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[621 .337]

Individual axle drive.

Mechanical systems used on electric locomotives and motor coaches, with an indication of the results obtained in service on railways of all kinds,

(Continued)*

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These 80 locomotives, series 7601 together with the three series briefly described in Chapter II (in the table following fig. 417) complete the new programme of the Spanish National Railways (RENFE) (288).

Before proceeding to a short description of the other series (France and Holland) and isolated locomotives of this type, all equipped with Als-Thom drive, we will deal with the development of this mechanism as well as certain suspension and side control arrangements fitted to all these series of locomotives.

This Als-Thom coupling is frequently called the « floating ring » type, but it is characterised by the push rod chiefly, the floating ring serving only as a link between pairs of rods and being itself a kind of coupling in the form of a ring because it encircles the axle near the journals.

The operating principles of this mechanism have already been described (289) and figures 430, 431 and 432 show recent applications of it with their variations. Figure 430 in particular gives in the sub-title the names of the various component parts, which allows the principle of operation to be followed exactly. The hollow shaft is fairly similar to that shown in figure 26 (290); it differs mainly because of the smaller diameter of the driving wheels [1 250 mm (4′ 1 7/32″) instead of 1 750 mm (5′ 8 7/8″) in the case of the

(*) See *International Railway Congress Bulletin*, for February 1953, p. 65.

(288) See *AFAC*, No. 177, end of 1952, pp. 149-153, « L'Electrification des Chemins de Fer Espagnols », 7 figures and tables, D. CAIRE. — Notice that one of the diagrams of the C_0C_0 locomotives, series 7601 at the bottom of p. 150 of the above mentioned publication, differs considerably (particularly in wheelbases, from the type of bogie and casing, of the RENFE locomotive shown in fig. 429).

(289) See pp. 896-901 of *Congress Bulletin*, October 1947 (pp. 29 and 31 of *Vol. II*, figs. 23, 25, 29 and 30).

(290) See p. 898 of *Congress Bulletin*, October 1947 (p. 30 of *Vol. II*).

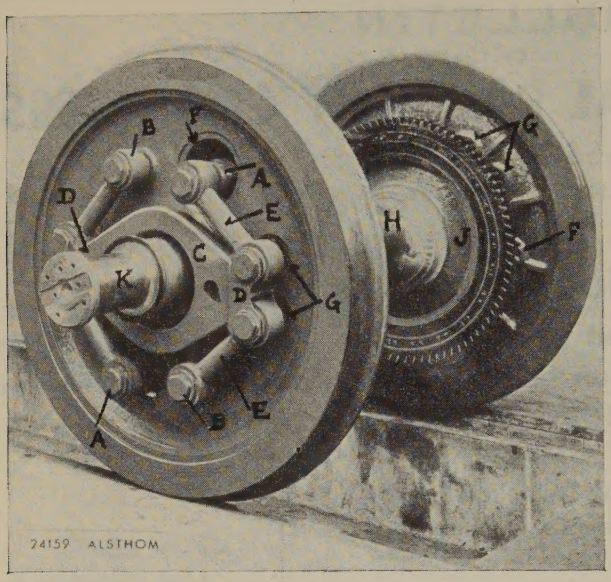


Fig. 430. — Assembled axle for prototype locomotive 7001/2 SNCF, type C_0C_0, put into service in 1948 (see figs. 282-283). Als-Thom push rod mechanism, with silent blocs, floating ring; bilateral gears (cf. fig. 25, 26, and 341 where the gear is unilateral). Wheel diameter : 1250 mm. The push rods and floating ring are of pressed and welded plate.

A = transmission pins fixed to gear wheel.
B = pins fixed to driving wheels.
C = floating ring (for connecting and retaining the 2 groups of push-rods).
D = lugs of floating ring C.
E = push rods with silent-blocs at the ends (see fig. 27).
F = openings in the driving wheels for passage of pins A.
G = spaces in the driving wheels, allowing free play of lugs D (question of space
H = hollow shaft.
J = gear wheel body.
K = journal with axlebox sealing ring (Athermos).

5301-5306 series ([291]) SNCF, shown in figures 22, 23, 25, 29 and 30] and the consequently smaller power per axle. The hourly rating at rail, per axle, was in fact for the 5301-5306 series about 1 020 HP, whilst that of the 7101 series locomotives (again SNCF) is only 725 HP, still at an average line tension of 1 350 V. In addition, the load per driving axle, was, for the 2 D_0 2 series 5301, 20 tons (which could be increased to 22 tons by ballast), whilst for the 7101 series the axle load was only 17.8 tons. The Netherlands locomotives have a slightly higher axle load, 18.5 tons (including 5 tons of ballast) for the C_0C_0 1301 series, and about 19.6 tons (with 5.75 tons ballast) for the 1101 B_0B_0 series ([292]).

The mechanism itself (floating ring and push rods) mounted round the hollow shaft is always bilateral, whilst the gear may be either bilateral or unilateral. The bilateral gear must necessarily be *flexible*, but the unilateral gear fitted is *rigid*.

([291]) The 2 D_0 2 machine No. 5301, previously bore the number of the series E. 703 (see fig. 22 *Vol. II*).

([292]) See *AFAC*, No. 166, January-February 1951, table on p. 10, in « Electrification on the Netherlands Railways », A. NYMEYER. This table, however, contains an error in connection with the gears of the BB series 1101 and CC series 1301.

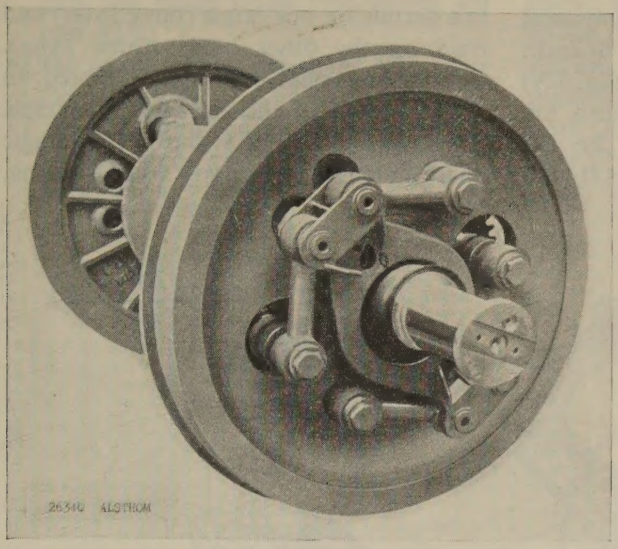


Fig. 431. — Assembled axle for Netherlands NS, locomotives series 1101 (B_0B_0) and 1301 (C_0C_0) with mechanism similar to fig. 430; same wheel diameter; floating ring lugs reinforced with fillets. View from unilateral gear side; in the background is the end disc of the hollow shaft drive (cf. fig. 26).

This is exactly the same coupling as used on the CC locomotives, series 7600, of Spanish RENFE.

On all engines with a rigid unilateral gear, angular flexibility is assured by the silent blocs of the floating ring couplings, which are always mounted, as we have shown, on each wheel. This is to ensure that there shall be — in *either direction* of travel — some rods in tension and some in compression; it is, in effect, necessary to limit the springing of rods in compression.

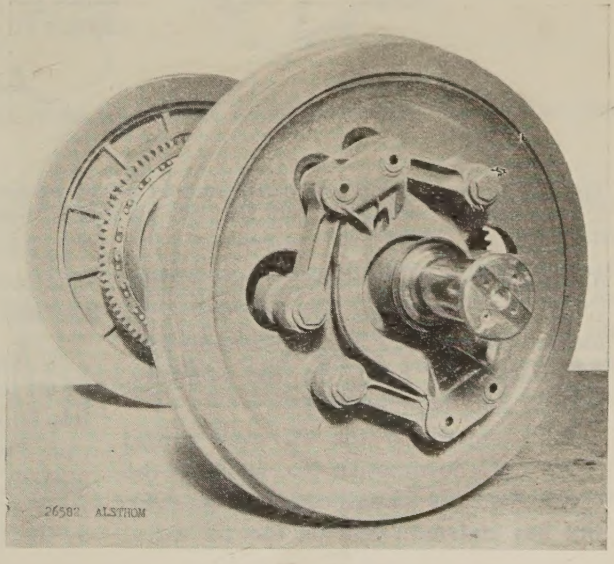
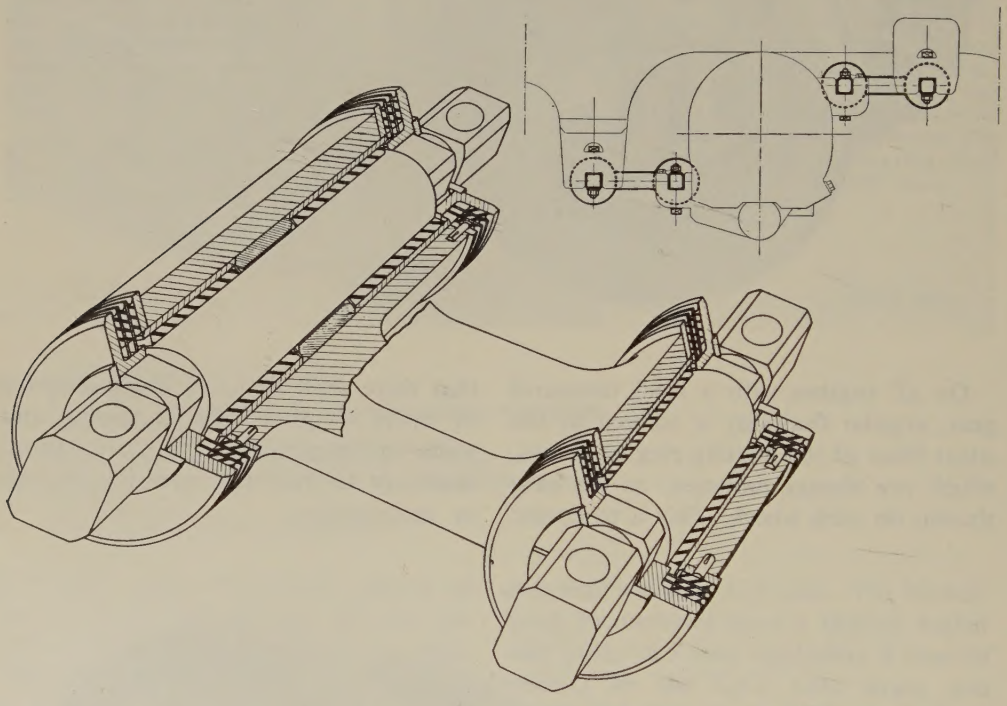


Fig. 432. — Assembled axle of first 43 C_0C_0 locomotives, series 7101, SNCF. The mechanism is the same in principle as figures 430 and 431, with bilateral gear (as fig. 430). The push rods are die stamped to reduce cost. From locomotive No. 7144, gear will be unilateral.

In connection with bilateral or unilateral gears, we may note that the 80 Spanish locomotives (RENFE) series 7601 (fig. 429) have *rigid unilateral* gears, so have the 60 Netherlands locomotives of the NS (series 1101 and 1301, figs. 292, 431 and 438-441) and the 10 SNCF locomotives (Nos. 7144-7153, figs. 431 and 438-439); locomotives 7001/2 (figs. 282 and 283) and 7101-7143 have, on the contrary, flexible and bilateral gears.

With regard to the 50 cycle single phase C_0C_0 locomotive No. 6052, of the SNCF, already described (see fig. 426), this has unilateral gear on the six axles, but flexible on one bogie (three axles) and rigid on the other bogie (three axles). This arrangement has been adopted to allow a study of the influence of flexible couplings on the behaviour of the single phase motors, particularly when starting. The practical operating results will provide useful data for further development.



Plan Alsthom.

Fig. 433. — Arrangement and partial sections of link between axlebox and bogie frame; Als-Thom system. Articulated push rods with silent-blocs — see sectional views. Cf. fig. 401.

In respect to the suspension and control of all locomotives of these types built by Als-Thom (in collaboration with the Traction Departments of the Railways concerned), we may mention here :

a) the connection between the axleboxes

and the bogie frame (see figures 401 and 433);

b) the recoil springs inside the axle boxes (see fig. 434);

c) the oscillating bogie pivots with controlled lateral recoil (see figs. 435 and 436; cf. fig. 283).

allow vertical movement of the axle whilst its centre line is held in the same vertical plane. This is one of the recognised modern devices for eliminating vertical rubbing blocks of the normal type (293). It dispenses with lubrication, wear, and play between axleboxes and

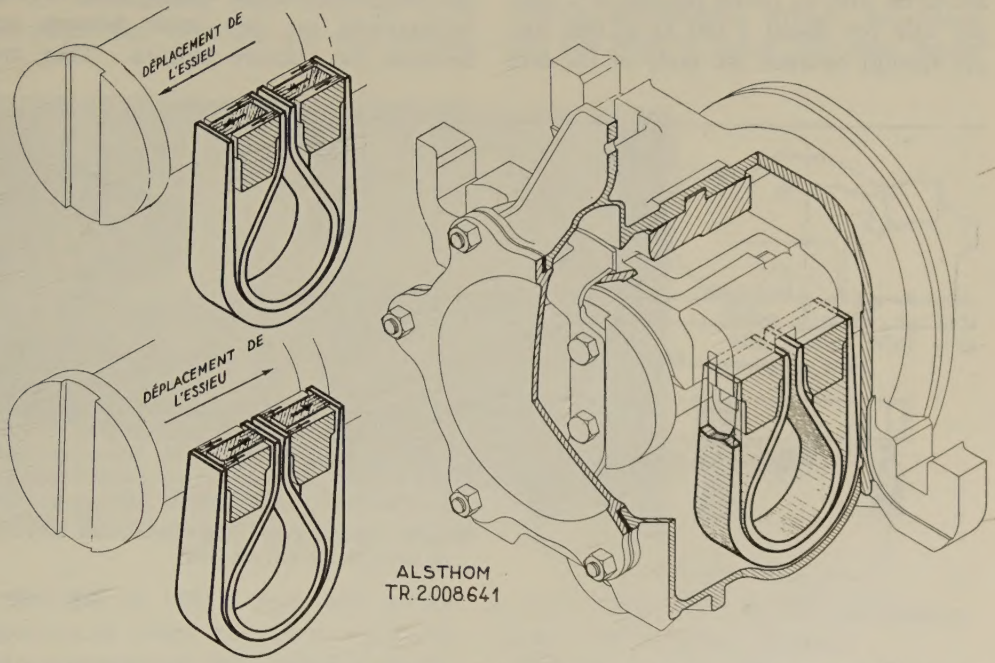


Fig. 434. — Recoil springs on the inside of the axleboxes for damping transverse shocks due to track faults (see text).

These parts are in effect closely connected with the type of coupling; in principle, they are applicable to all classes of rolling stock. The following remarks may be made in this respect :

ad a) The articulated links with silent blocs hold the axle box by two lugs arranged on an oblique diameter to frame; it also provides a certain degree of transverse flexibility to facilitate entrance to curves. The squared ends of the silentblocs are fitted without play in square sockets, machined to suit, in the axlebox lugs and in the bogie frame. They are easily assembled and dismantled by bolts.

(293) For comparison with other systems, see, for example, figures 368, 145, 154*a*, 159, 162-166, 184-186, 188 of *Vol. II* and later ones.

ad b) In addition to the transverse resilience provided by the silent-blocs in the links noted under *a)* the bearing of the axleboxes (in the case of the « Athermos » boxes mentioned) can slide axially by 10 mm (25/64″). The very flexible flat springs shown in figure 434, U-shaped, are fitted with an initial tension of 5 tons per axle [or about 1 250 kg (2 666 lbs) per spring] between the body of the box and the bearing. There are four springs per box, one of each type, spaced round each journal. These are stress dampers which come into play only when the transverse reaction of the locomotive on the track reaches about 5 tons per axle. The undesirable reaction can thus barely exceed about 5 or 6 tons, which increases the security from derailment. It is of course necessary to bear in mind the ever increasing speed of operation on main lines.

ad c) In most modern C_0C_0 type locomotives, the body rests on each bogie by means of *two* pivots located between the axles. It is, moreover, known that 3-axle bogies are not particularly favourable, whatever their application, in certain respects. On the Als-Thom locomotives, these pivots can oscillate with a double articulation on rubber cones and bear (in the longitudinal centre line of the locomotive) on two cross bearers set between the traction motors. They are connected transversely to the body by flexible arms (a kind of recoil arm) as can be seen at the bottom of figure 435 and shown in figure 436 with the pivot. The oscillating pivots together with these arms allow a maximum angularity of the bogies in relation to the body for taking a curve of 80 m (4 chains) radius. The lateral recoil arrangements improve the stability.

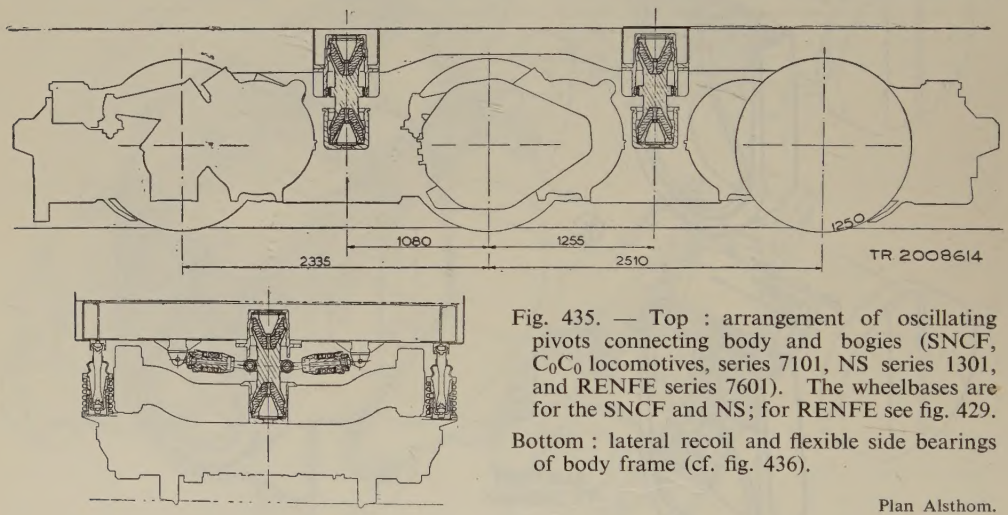


Fig. 435. — Top : arrangement of oscillating pivots connecting body and bogies (SNCF, C_0C_0 locomotives, series 7101, NS series 1301, and RENFE series 7601). The wheelbases are for the SNCF and NS; for RENFE see fig. 429.

Bottom : lateral recoil and flexible side bearings of body frame (cf. fig. 436).

Plan Alsthom.

We can now pass to a brief description of the principles of the Als-Thom locomotives, types B_0B_0 and C_0C_0, commencing with the 7101 series, C_0C_0,

SNCF, which is without doubt the one most discussed (294). As already mentioned, there are the two prototypes, Nos. 7001 and 7002 [see figs. 282, 283 and 430, also note (184)] placed in service — after trials — on the 3rd May and the 28th October 1949, and the series of 53 locomotives Nos. 7101 to 7153 (of which No. 7106 was put into service at the end of 1952; and 7107 at the beginning of 1953; the others being still under construction) which are not absolutely identical. We have already indicated in comparing them with the Netherlands and Spanish locomotives, that the prototype locomotives 7001 and 7002, as well as the first 43 engines of the series (7101 to 7143) have *flexible bilateral* gears, whilst the following 10, Nos. 7144 to 7153 have *rigid unilateral* gears.

In the case of the bilateral flexible gear, this is achieved by means of helicoidal springs and couples bearing on the movable geared rim and a block solid with the hollow shaft, similar to the various applications already mentioned (see also what is stated later with regard to the « Alben-SW » flexible transmission of the SNCF motor coaches).

The 45 engines 7001/2 and 7101/43 are equipped with the Als-Thom TA. 621 motor, which has been provided to realise trial speeds in the region of 200 km (124 miles)/h with a gear reduction of 1 : 2.606. The 10 engines 7144/53 on the other hand are equipped with the

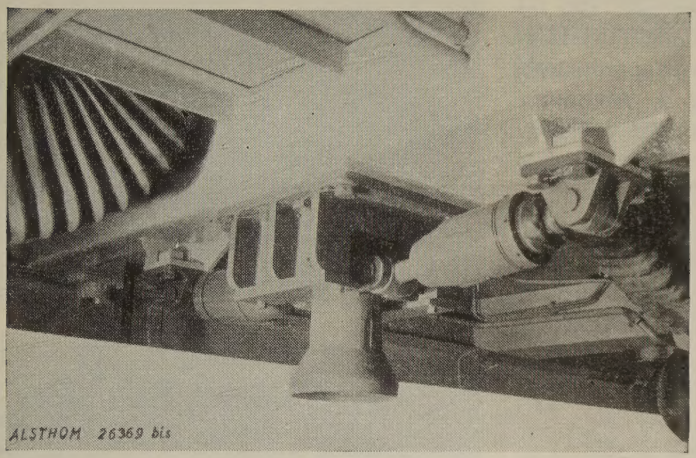


Fig. 436. — View of oscillating pivot (cf. fig. 435) with flexible recoil rods under the body.

(294) See *RGCF* numbers as under :

— June 1949, pp. 247-248 (figs. 9 and 10) in « Electric locomotives for 1 500 V D.C. — Their technical development », by GARREAU;

— September 1949, pp. 385-393 (9 figs.), « Electric locomotive CC 7001 of the S.NCF », by J. TROLLUX.

See also *AFAC*, No. 175, July/August 1952, pp. 102-116, 27 figures, by D. CAIRE.

— *EB*, No. 4, 1950, p. 94 (comparative table of recent SNCF locomotives) and figure 6.

Als-Thom TA. 628 motor, shown in figure 437, with a gear reduction of 1 : 2.96, allowing a maximum speed in service of 160 km (100 miles)/h. These motors, for 750 V at the terminals (insulated for 1 500 V) are always paired in series.

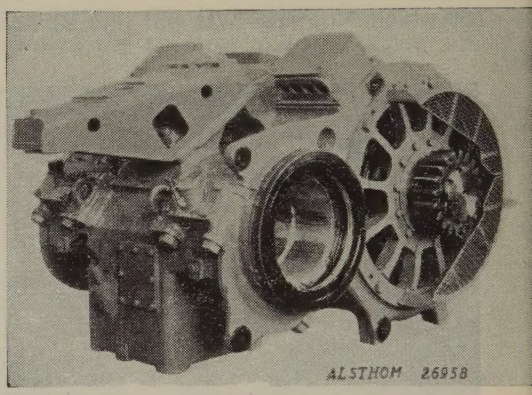
The same TA. 628 motor (fig. 437) which weighs only 3 500 kg (7 716 lbs.) nett, or 7.7 kg (18 lbs.) per kgm of torque, has been used also for the 60 Netherlands locomotives B_0B_0 1101-1150 and C_0C_0 1301-1310, but with a reduction ratio of 1 : 3.7 allowing a maximum speed in service of 135 km (83 miles)/h.

This is a very profitable standardisation as this motor serves a quantity of locomotives (70 so far) in two countries. The TA. 628 motor has replaced the TA. 621, and is of more economical construction and also gives complete satisfaction.

We indicate, below, the builders of the SNCF locomotives, series 7101-7153, type C_0C_0 with Als-Thom coupling:

Of the first batch of 30 locomotives (Nos. 7101-7130) the first fifteen were constructed entirely in the Als-Thom works; the next fifteen by the « Compagnie de Fives-Lille » for the mechanical parts and the « Compagnie Electro-Mécanique » for the electrical equipment. Of the second batch of 13 machines (Nos. 7131 to 7143), the first 7 (Nos. 7131/37) were built by Als-Thom, the following 6 (Nos. 7138-43) by « Fives-Lille » and « C.E.M. », as above. The third batch of 10 (Nos. 7144-53) are split 5 and 5 as for the other batches. These last 10 are, as already stated, those which will have the Als-Thom TA. 628 traction motors (2 photos of fig. 437).

In connection with the above, figure 438 is a general plan of a complete bogie of the C_0C_0 locomotives of the SNCF and NS. Figure 439 is a general view. The bogie frame, as will be seen, is greatly simplified as it comprises only two sole-bars, which are clearly shown, with tubular outer headstocks and the two



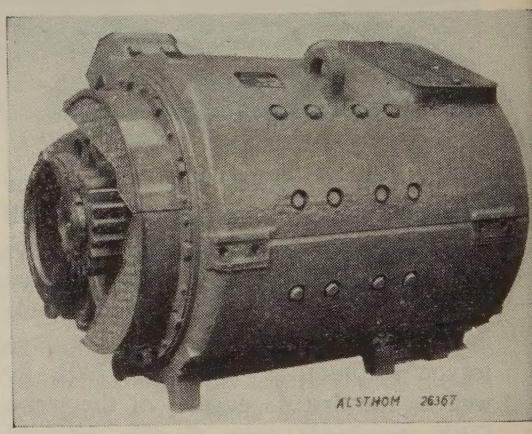
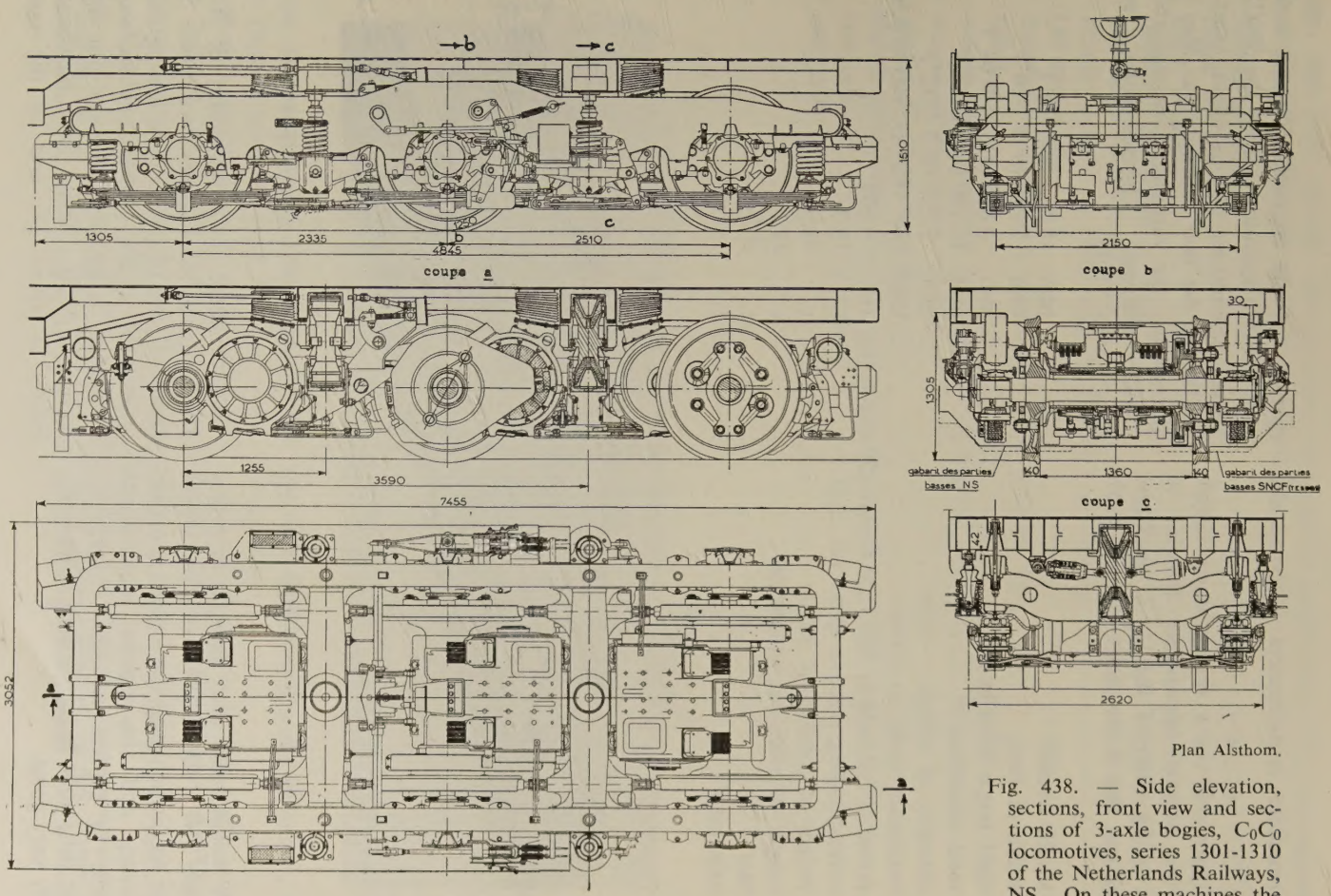


Fig. 437 (*a* and *b*). — View of TA.628, Als-Thom, motor fitted to SNCF C_0C_0 locomotives 7144-7153; also to 60 NS (Netherlands) B_0B_0 locomotives, series 1101/50, and C_0C_0 1301/10.

Top figure *a* shows the motor and pinion, from the side of the hollow shaft, fitted in the housing.

In the lower figure *b*, the motor is again shown from the pinion side, but from the side opposite to the hollow shaft, showing the same end.



Plan Alsthom.

Fig. 438. — Side elevation, sections, front view and sections of 3-axle bogies, C_0C_0 locomotives, series 1301-1310 of the Netherlands Railways, NS. On these machines the gear is unilateral and rigid. Cf. figs. 283 and 431-347. The SNCF bogies of series 7101 are very similar.

intermediate cross-bearers carrying the pivots.

Figure 440 is a dimensioned sketch of the general appearance (similar to that of fig. 282) of the C_0C_0 Als-Thom machines, that is the series 1301 (10 locomotives for the Netherlands) and series 7101 [53 (55) locomotives] for the SNCF. These locomotives are in effect exactly similar on the two Railways, as also in dimensions : the variations are negligible.

The principal characteristics are (SNCF, No. 7101):

— length overall	mm	18 922 (62′ 7/8″)
— width of body	mm	2 968 (9′ 8 7/16″)
— rigid bogie wheelbase	mm	4 845 (15′ 11 9/64″)
— total wheelbase	mm	14 140 (46′ 4 1/2″)
— diameter of wheels — new	mm	1 250 (4′ 1 7/32″)
— maximum speed in service	km/h	140, 160 (87, 100 m.p.h.)
— power at full field (1 500 V, at 80 km [50 m.p.h.])/h	HP	4 800
— corresponding tractive effort (at rail)	t	15.7
— weight of mechanical parts	t	94.9
— weight of electrical equipment	t	42.1
— tare	t	107
— axle load	t	17.8

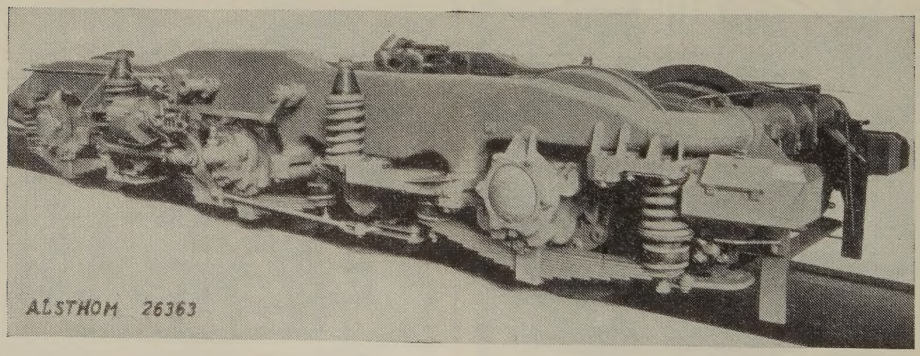


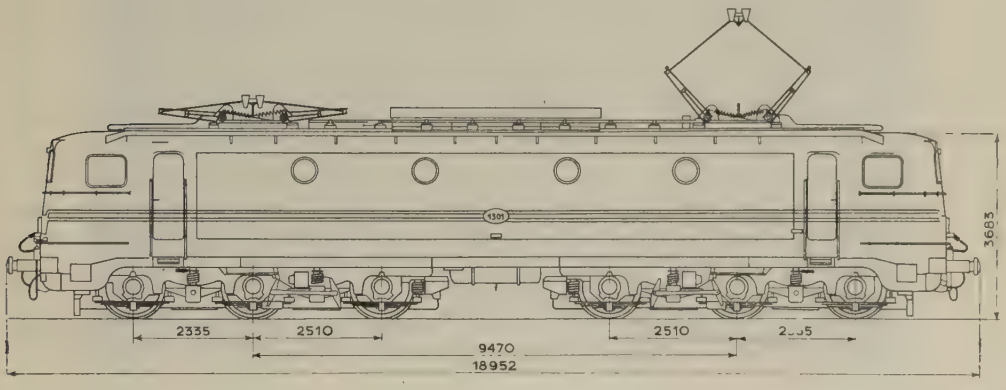
Fig. 439. — View of bogie of fig. 438. The simplicity of the frame will be seen.

It would seem that these locomotives of the SNCF series 7101 are those which have so far achieved the highest monthly mileages and the greatest commercial speeds in express service. Moreover, their behaviour at high speeds is undoubtedly very good.

To conclude the large series of Als-Thom drive locomotives, we show in figure 441 one of the 50 B_0B_0 locomotives series 1101 of the Netherlands Railways in service. The first 25 were put into service in 1950. These were mentioned briefly in figure 292 and on the same

page, and have already been described in technical publications ([295]); consequently we shall only give the main characteristics :

— length overall	mm	12 984 (42′ 7 9/32″)
— bogie wheelbase	mm	2 950 (9′ 8 1/8″)
— total wheelbase	mm	8 950 (29′ 4 3/8″)
— diameter of wheels — new	mm	1 250 (4′ 1 7/32″)
— maximum speed in service	km/h	135 (84 m.p.h.)
— hourly power at full field (1 500 V, at 78 km [48 m.p.h.]/h)	HP	3 100
— corresponding tractive effort, at rail (in parallel: full field)	kg	10 500
— weight of mechanical part (body and bogies)	t	42.6
— weight of pneumatic equipment	t	2.9
— weight of electrical equipment	t	27.4
— ballast permitted, about	t	5
— trial weight — adhesive weight	t	78
— axle load	t	19.5



Plan Alsthom.

Fig. 440. — Dimensioned sketch of C_0C_0 machines, Als-Thom series 1301, NS, applicable also to SNCF series 7101.

On all these locomotives fitted with Als-Thom transmission (B_0B_0 and C_0C_0 of three railway systems), this coupling has behaved very satisfactorily, as also have the arrangements *a)*, *b)* and *c)* of the bogies.

We will mention finally some other isolated applications of this Als-Thom

([295]) See *Spoor- en Tramwegen*, number of 20th April 1951, pp. 119-125, 9 figures, « De electrische inrichting der nieuwe locomotieven type B_0B_0 der NS », by J.P. KOSTER.

Also *AFAC* of note ([292]) giving relative to the BB, 17 figures, diagram and comparative statement (the mechanism shown in the first figure is of prototypes SNCF 7001/2 of fig. 430, instead of fig. 431; furthermore, the fourth column of the table shows bilateral flexible gears, which is wrong).

mechanism. It is fitted on one of the prototypes No. E. 10.001, of the new E. 10 locomotives of the Federal Railways of Western Germany — Deutsche Bundesbahn, D.B., This is one of the four prototypes (E. 10.001 to E. 10.004/5) type $B'_0B'_0$, ordered at the end of 1950 (296) and still under construction at the end of 1952.

The other prototypes will be dealt with briefly in the chapters relating to their type of transmission. The prototype machine No. E. 10.001, is fitted with a coupling similar to that of figures 430 to 432; the gear is flexible and bilateral with oblique teeth. It was built by the Krauss-Maffei locomotive works at Munich as regards the mechanical por-

Photo : Ing. Ad.-M. Hug.

Fig. 441. — NS locomotive $B'_0B'_0$, No. 1121, hauling a train for Utrecht at the SS station, The Hague. (Fitted with arrangements as fig. 431 and 433-437, with Isothermos boxes).

(296) See *EB*, No. 12, December 1951, pp. 313-314 (1 fig., 1 table), « Neue elektrische $B'_0B'_0$-Lokomotiven Reihe E 10 für die Deutsche Bundesbahn », E. KILB.

The other prototypes are equipped with the following mechanisms :

— E. 10.002 Brown Boveri disc and cardan joint, fitted in the motor centre line (already known, see figs. 245-247);

— E. 10.003 new SSW (Siemens) mechanism with hollow shaft constituted by 6 sectors of rubber disc, with bilateral drive by 6 arms fitted to the gear body;

— E. 10.004 and 005, Secheron leaf spring and cardan joint in the armature centre line (already known, see figs. 258, 259, 374 and 375).

tion and the electrical equipment was supplied by A.E.G. Wheel diameter is 1 350 mm (4′ 5 1/8″).

Apart from the Als-Thom flexible coupling, with push rods and silent blocs, other Als-Thom arrangements have been used on this locomotive, including linking the boxes to the bogie frame by links fitted with silent blocs (*a*, see fig. 433) and oscillating bogie pivots with flexible recoil rods and rubber cones (*c*, see figs. 435 and 436).

With regard to the use of the Als-Thom coupling on *Diesel-motored vehicles*, we will briefly mention the matter here and deal with it more fully in the final Chapter VIII, concerning flexible transmission to axles driven by internal combustion engines. Fig. 291 ([297]) shows a section of a driving axle and gear box of the SNCF railcar XX. D 4006; we shall describe this, therefore, at the end, together with the two prototype Diesel locomotives 030. DC. 1 and 2, of the SNCF ([298]).

CHAPTER IV.

DRIVE MECHANISMS WITH SPRINGS (or rubber) AND TRANSMISSION THROUGH GEARS. ([299])

In previous publications, this chapter has commenced with helicoidal spring mechanisms (almost always with hollow shaft and gears) of the « quill-drive », American type, and its derivatives ([300]). Apart from a certain number of electric locomotives in recent years (particularly the Austrian Federal Railways BBOe) which we shall describe later, it must be admitted that there will be no future applications of couplings such as the « quill-drive », the « Sécheron II and III », those with helicoidal springs in sockets (« quill cup » or « Federtopf ») and others of the same kind.

Amongst the derivatives of the « quill drive », the following are particularly interesting:

1) the mechanism, which we have called the « Sécheron I » (first application about 1921) ([301]) comprising several twin springs located symmetrically on each side of each of the driving arms (around the ends of the hollow shaft);
2) the mechanisms with spring sockets, i.e. the « quill cup drive » of the Westinghouse Corporation of the U.S.A. and the « Federtopfantrieb » of the German A.E.G., both comprising helicoidal springs in pairs socketed between the arms ([302]).

Many of these mechanisms, particularly in the U.S.A. and Scandinavian countries (Sweden, Norway) have been converted, in so far as the helicoidal (so-called coil) springs have been replaced by rubber pads (see for example, figs. 115, 116, 117,

([297]) See *Congress Bulletin*, May 1949, pp. 393-394 (pp. 232-233 of *Vol. II*).
([298]) See *RGCF*, January 1951, pp. 3-9, 9 figures and 1 table, « Diesel mechanical locomotives, prototype 030-DC-1 and 2 SNCF », by Ch. Tourneur (see figs. 3, 6, 7 and 8).
([299]) See *Congress Bulletin*, December 1947, February, April, July, October and November 1948, and supplement November 1949 and January 1950.
([300]) *Vol. I*, pp. 36-53 (figs. 13, 36-37, 72-112, table p. 52). *Vol. II*, pp. 37-114, 234-260 (figs. 32-66, 67-107, 108-112, 118-128, 294-304, 343-347).
([301]) Figures 94 and 96 of *Vol. I*; 37, 49, 51, *Vol. II*.
([302]) Figures 102 to 105 of *Vol. I*, and 67 to 76 of *Vol. II*.

323-325 of *Vol. II*). For this reason, apart various similarities, they have also been covered in Chapter IV, relating to drive mechanisms with rubber components. It would have been more logical to survey the whole of the couplings with rubber elements in a separate Chapter, but it is

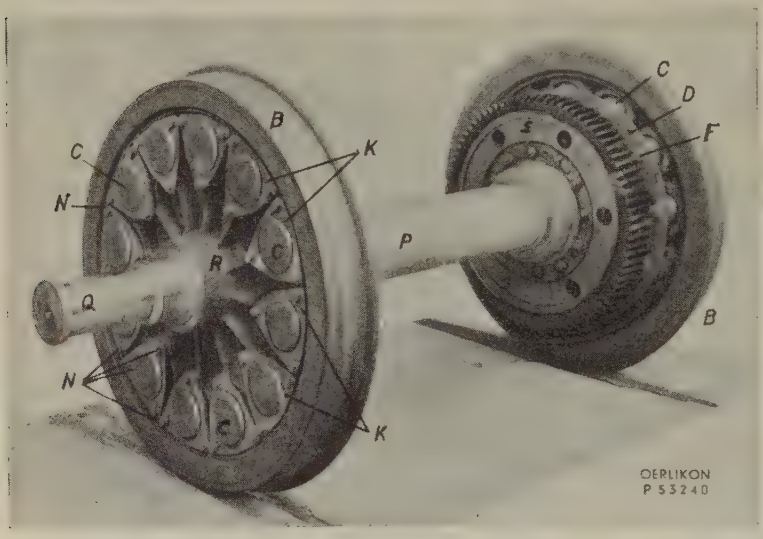


Fig. 442. — Complete driving axle (without motor or gearcase) with Oerlikon driving mechanism, reinforced rubber elements, for motor luggage vans, class Fe 4/4, Nos. 821-824, Swiss Federal Railways, CFF. Bilateral mechanism on hollow shaft, unilateral gear; cf. figs. 197, 198 and 444.

P = hollow shaft.
S = gear wheel.

(for other designations, see fig. 443).

considered that at present, this would be premature. The couplings with rubber components, moreover, fall into various categories of flexible drive mechanisms.

We may also note in passing that the « Meyfarth-Sécheron » mechanism (which we have called « Sécheron II », see pp. 95 to 114 and 269-271), which was used in Switzerland (BLS, CFF, etc.), in Sweden (SJ, GBJ), in Hungary (MAV) and in France (SNCF, twin Diesel-electric locomotives of the PLM) has given rise in most cases to excessively high maintenance costs (fracture of standards, heavy wear of sockets). Many of them have consequently been converted, either to « Sécheron I » or to Pennsylvania type « rubber-drive » (see p. 270 *Vol. II*). We shall not discuss these further, as they may be considered obsolete. There are now some isolated locomotives or motors still equipped with the « Sécheron II », which have been described in the appropriate places.

We shall also no longer discuss the « Sécheron III » coupling ([303]), shown in figures 194-196, which has had no further application since the single prototype driving axle fitted in 1948 to the CFF Re 8/12 set No. 691. It has quickly been superseded by the « Sécheron IV » laminated spring type, which will be discussed in Chapter VI, and which is

([303]) See *Vol. II*, pp. 152-154 (*Congress Bulletin*, November 1949).

one of the most interesting at the present time.

We shall deal first with some new mechanisms (or partly new, since they are re-builds), then report successively the majority of the new applications of mechanisms used during the past twenty years at the most. Finally, some recent applications of mechanisms of older design.

The « Oerlikon » coupling shown in figures 197, 198 and 342 (which we may call « Oerlikon VI », taking as V that in figures 143-145 and VII the laminated spring type with triangles) was first used in 1943 with spiral steel springs (figs. 197-198), then converted in 1948 with rubber elements in place of springs (fig. 342). Since the prototypes already described, this coupling has been improved; the new fitting is shown in figures 442 and 443. The operation is as described earlier (304), except that the rubber elements have been replaced by spiral springs. A comparison of figures 443, 197 and 342, then 442 and 198, shows the improvements made in the mechanism; the components are detailed in the sub-title to figure 443.

This improved coupling has been fitted to four motored luggage vans of the Swiss Federal Railways, CFF, Fe 4/4, Nos. 821 824. One of these is shown in fig. 160 (305), and they have been renumbered in the new series 801-824 (306). Motor van No. 824 has only one bogie (two axles) fitted with this new Oerlikon mechanism, whilst the three numbered 821, 822

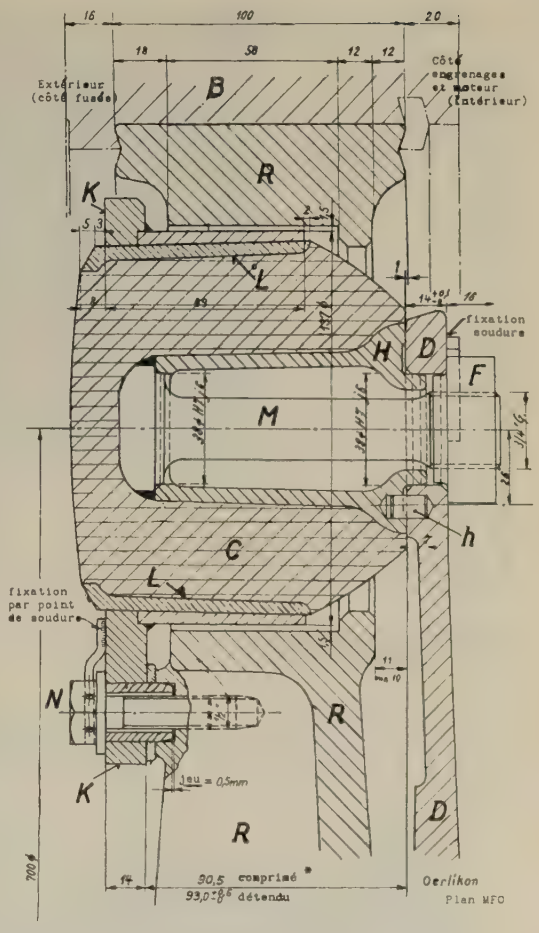


Fig. 443. — Part section of axle in fig. 442, on diametral plane through a reinforced rubber element, set in the wheel disc (cf. fig. 342) :

R = wheel disc.
B = tyre
D = hollow shaft disc, carrying pins M (cf. fig. 197).
M = dividing pins (12 per wheel) with spheroid ends.
F = fixing screw for pins M.
C = rubber sleeve.
H = interior fixing plate for rubber unit C.
L = outer, ditto.
h = pin fixing H to D.
K = outer fixing triangles for attaching C to the plate L (see fig. 442).
N = bolts for fixing triangles K.

(304) See *Vol. II*, pp. 154-156 (*Congress Bulletin*, November 1949).

(305) See *Vol. II*, p. 127 (*Congress Bulletin*, November 1949). The legend has been reversed with that for figure 42 in error.

(306) See p. 294, *Vol. II*, relative to the « Sécheron » leaf-spring mechanism and its use on the CFF (*Congress Bulletin*, January 1950). — On this series of motor luggage vans (old numbers 18501-18524 and 18561), some converted and some new bogies have been used.

and 823 are fully equipped, a total of 14 axles being in service, similar to that in figure 442. In figure 444 is a dimensioned sketch of these motor luggage vans now having the numbers of the series 801-824 and 831. The weights are also shown, for each axle (left hand column = tare; right hand column = weight in running order when loaded (luggage, parcels, mail). The remaining principal details of these motor coaches (not given in fig. 444) are as follows :

Motor coaches Nos. :	801-11	812-24	831
Transmission ratio (gears)	1 : 4.235	1 : 3.6	1 : 4.235
Transmission ratio with new axle coupling	1 : 5.143	1 : 4.235	—
Maximum weight (loaded) t	67.2	63.6	69.8
Weight in running order t	62.2	58.6	64.8
Load area (including mail) m^2	21.0	21.0	20.5
Permissible pay load t	5.0	5.0	5.0
Maximum tractive effort at rail kg	10 400	8 800	8 800
One hour tractive effort at rail kg	7 000	5 960	5 960
One hour power at rail HP	1 100	1 100	1 100
at a speed of km/h	42	50	50
Maximum speed in service km/h	75	85	85

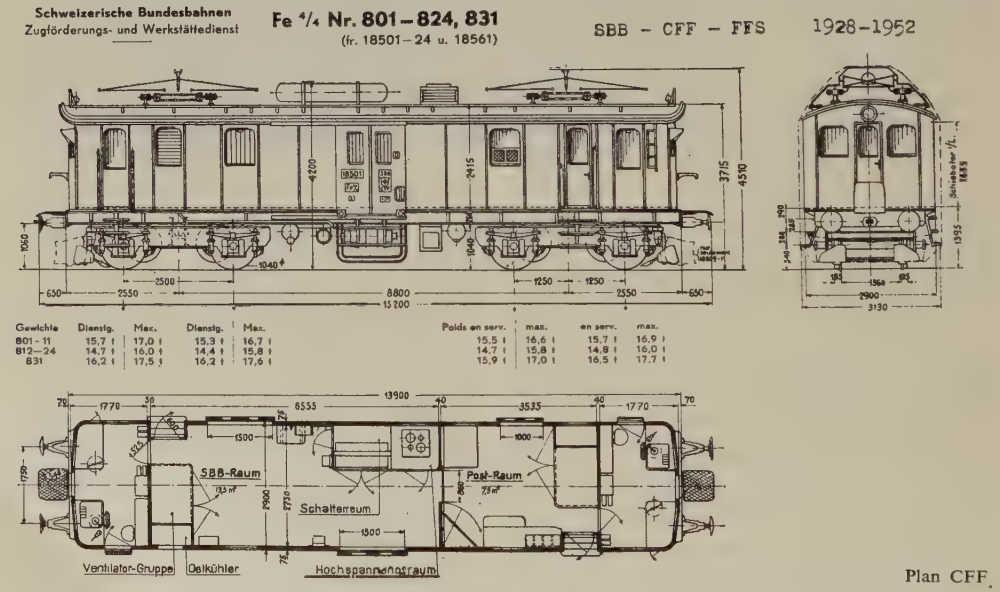


Fig. 444. — Diagram with dimensions and weights of motor vans, series 801, class Fe 4/4 (old series 18.501-18.524) of the Swiss Federal Railways, CFF, with either Oerlikon with reinforced rubber elements or Secheron leaf springs and cardan joints, or nose suspended motors as originally fitted. Of all these motor coaches, two have converted bogies, the others have new bogies.

N.B. — The coaches were built in 1928 and have now been modernised. See detail Chapt. VI.

Fig. 445. — Motor coach No. 401 of the Rome-Ostia-Lido (STEFER) Railway 1952, with new Breda rubber coupling, at Rome S.Paolo Station.

Photo Breda.

These are fairly old motor vans (they were put into service in 1928 and by 1953 are consequently 25 years old already), which have now been modernised. Twelve of the luggage vans, Nos. 801-811 and 831, have regenerative brakes.

We shall deal later with new applications of the « Bianchi » Italian mechanisms (for locomotives and for motor coaches or sets), « Negri I » and «Negri II » (307) and refer now to *new* Italian rubber couplings.

The Breda Company, already often mentioned, now the « Breda-Ferroviaria » company of Milan (Sesto-S.-Giovanni) has developed since 1948-1950 some new rubber mechanisms (308).

The first is that used on four axles of

Photo Breda 2744/754

Fig. 446. — Bogie (complete with motors) of Fig. 445, with Breda rubber drive and RIV roller bearing axle boxes.

(307) Figures 199 to 204; 306 to 314, 318, *Vol. II* (*Congress Bulletin*, October 1948 and November 1949).

(308) Manufacturer Ant. Sbrighi, of Breda, Italian patents Nos. 421991 and 442349, granted in 1947/1948.

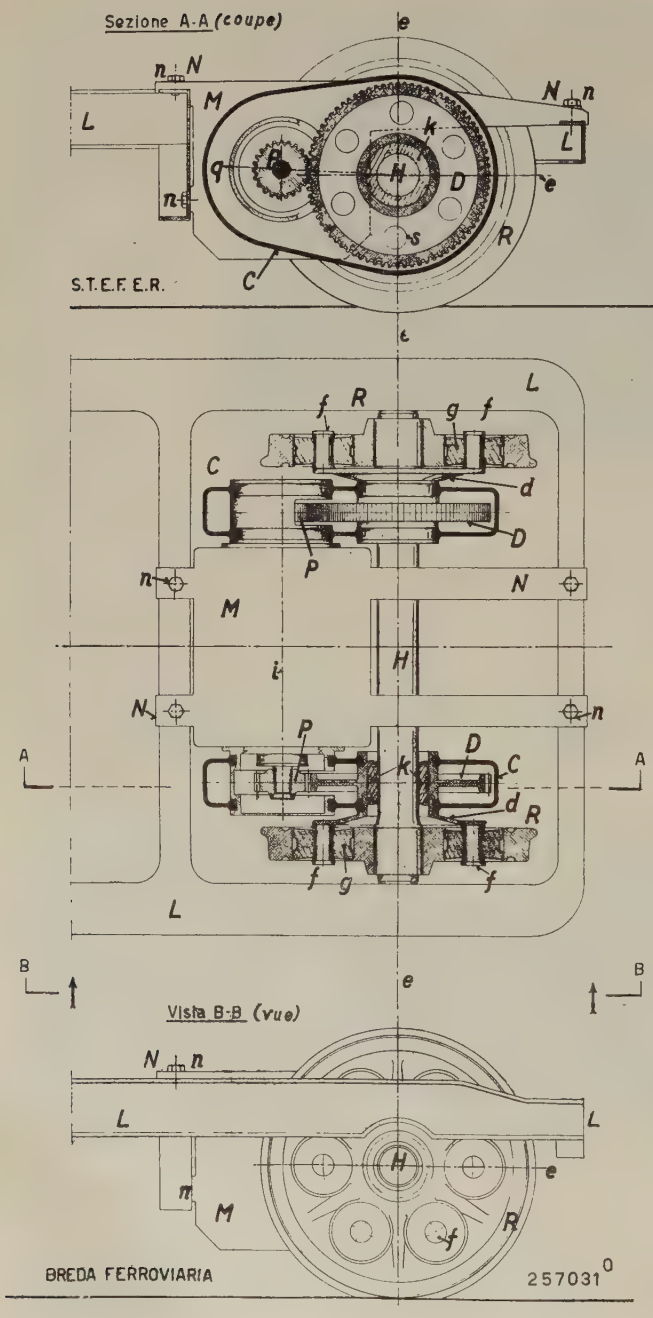


Fig. 447. — Diagram with vertical section (gear and gearcase), horizontal section through axle centre line, and elevation of Breda mechanism (for STEFER motor coaches, cf. figs. 445 and 446).

M = traction motor.

L = bogie frame.

N = motor support arms and fixing points *n* on cross members of bogie frame L.

H = axle.

R = wheel (disc with tread and hub).

D = gear wheel with dished plate disc *d*, carrying the six driving pins *f* of the wheel R.

P = pinions keyed to armature shaft of motor M.

C = gearcase, pivoting slightly about the axis *i* of the armature of motor M, thus varying the angle between the horizontal axis *e* of the axle and the centre line *q* of the gears (at the top).

f = driving pins.

g = rubber blocks framing the pins *f*.

k = rubber ring rotating without friction with the gear wheel D (externally) and the axle H (internally).

e = axle centres.

s = spaces in the gear wheel centre (not connected with pins *f*).

N. B. — At all points of the gearcase C (shown in heavy lines) indicated (in the centre section) by T shaped ends, are ball bearings on either the axle centre line *e* or the centre line *i* of the armature.

Plan Breda.

motor coach No. 401, put into service in the spring of 1952, by the Stefer (« Società Tramvie e Ferrovie Elettriche di Roma ») Company, the Rome suburban railway system, which also operates the « Ferrovie Vicinali » and the « Tramvie Castelli Romani » ([309]).

Figure 445 shows the new motor coach No. 401 on the road at Porta S. Paolo, the first station on the line from Rome to Ostia. Figure 446 shows a complete bogie of this coach, in the Breda works.

Figure 447 is a diagram of the Breda rubber drive mechanism, in this case bilateral, as are the gears. The driving axles are thus perfectly symmetrical in relation to the longitudinal centre line of the bogie.

This mechanism can be described as follows (fig. 447): the traction motor M rests on four arms N (actually two arms and two lugs) ([310]) fixed by bolts *n* on the bogie frame L. The axle is consequently « pivoted » in relation to its suspension, on the armature centre line *q* which forms a small variable angle with the horizontal centre line of the wheels. The gear case C also moves, with the axle by means of ball bearings (encircling the gear wheel and sealing the gear assembly), on the axle H with the two gear wheels D and on the armature shaft (with a centre line *i*) with its two pinions P. The hub of the gear wheels D forms a sort of stub hollow shaft, lengthened on the wheel side by a plate disc *d*, which carries around its circumference the six driving pins *f*. These are placed concentrically in thick rubber discs *g*, which are in turn set (very much like very flexible silentblocs) in six cylindrical holes in the body of the wheel R. The axle centre lines are marked *e*, and the gaps in the gear wheel body (which have no bearing on the drive of the six pins *f*) are marked with the letter *s*. Finally, the space between the hub of the gear wheels D (this hub, as already stated, forming a stub hollow shaft) and the axle shaft H, is fitted by a heavy compressed ring K, of rubber, which is provided solely to limit the play of the gear wheel in relation to the axle, and conversely, that is to restore constantly the concentric position of the gear wheel D and the axle shaft H, to compensate the relative movements in various planes between the motor, gear-case and axle. The two latter parts rotate at the same speed, there is no friction of the packing ring on the cylindrical surfaces on which it bears, either

([309]) The Rome-Ostia-Lido, normal gauge, railway line joins (at the Porta San Paolo terminal) the Rome Metro (projected at the time of the planned World Exhibition 1942) which should be put into service in the spring of 1953, and which runs underground from the termini station via Colosseo to Porta S. Paolo. The Rome-Ostia-Lido line once belonged to the « Società Elettro Ferroviaria Italiana » SEFI and was operated at 3 000 V by reversible sets of BB locomotives and carriages, and by some motor coaches. — See *Congress Bulletin*, March 1935, « Increasing the capacity of a suburban line », 5 p., 5 figs. (with gradient profile and graphic timetable), Ad.-M. Hug.

After the second world war and its resultant damage, the line was taken over by the STEFER (provincial railways) and operated at a reduced tension of 1 500 V, being extended several miles southwards from Ostia, parallel to the Mediterranean coast.

([310]) The motor has a four point bearing (instead of 3) on the bogie frame. This does not, in this particular case, appear to be any disadvantage since the arms are both near the longitudinal centre of the bogie and being close together are not much affected by possible distortion of the bogie frame. Cf. pp. 51/52 of *Vol. II* (*Congress Bulletin*, December 1947, pp. 1013-1014).

to the inside (axle shaft H) or to the outside (hub of gear wheel D). This rubber ring K forms a new component, obviously not essential however, which has so far not been used in couplings of this kind.

The operation of this coupling can be summarised as follows: there are two « groups » flexibly connected to each other. One is the rigid « group » made up of the axle itself (axle shaft H and wheel centres R with the tyres) and the other is the rather less rigid « group » formed by the following parts: the bogie frame L, traction motor M with two pinions P, gearcases C, each with the gear wheel D engaging the pinion and carrying the pins *f* (six per wheel). These two « groups » move in relation to each other following the axle in comparison with the frame; these movements are flexibly compensated (or restricted, in another sense) by the rubber units *g*, in the wheels, and *k*, in the gear wheels. These rubber units *g* do not however carry any weight and serve only in transmission of the torque.

The traction motor has its own armature bearings — apart from the exterior ball bearings for the pinions — the two pinions P being fixed rigidly to the shaft. The four ball bearings of each gear case (concentric to the armature and, statically, to the axle shaft) transmit only limited efforts; those outside the pinions on the armature shaft are not really essential; they have been fitted with a view to noise reduction (particularly with wear and age).

In the case in question, the Breda mechanism is fitted with *bilateral* drive (gears and driving pins) but it can also be used with *unilateral* gears and driving pins. Moreover, it can also be fitted, where necessary and according to the distance between the motor and the axle, with an intermediate wheel as shown in the specifications ([311]).

No definite statement can yet (beginning of 1953) be made about the behaviour in service of this coupling, because it is fitted only on one motor coach (8 sets of mechanism on 4 axles) and also the motor coach has only been in service since April 1952. The manufacturers are of the opinion that there will be no wear on the component parts. They do not heat up in service, despite the haulage of four trailers, even under exceptional conditions, for example at frequent heavy peak loads during the summer holiday season [see publication mentioned in note ([309])].

In any event, up to the beginning of 1953, the coupling had not given any trouble.

This motor coach has a tare weight of 44 tons, which, with the pay-load, corresponds to an axle load of 12.5 tons. The maximum speed in service is 90 km (55 miles)/h; trials have been made at up to 110 km (68 miles)/h.

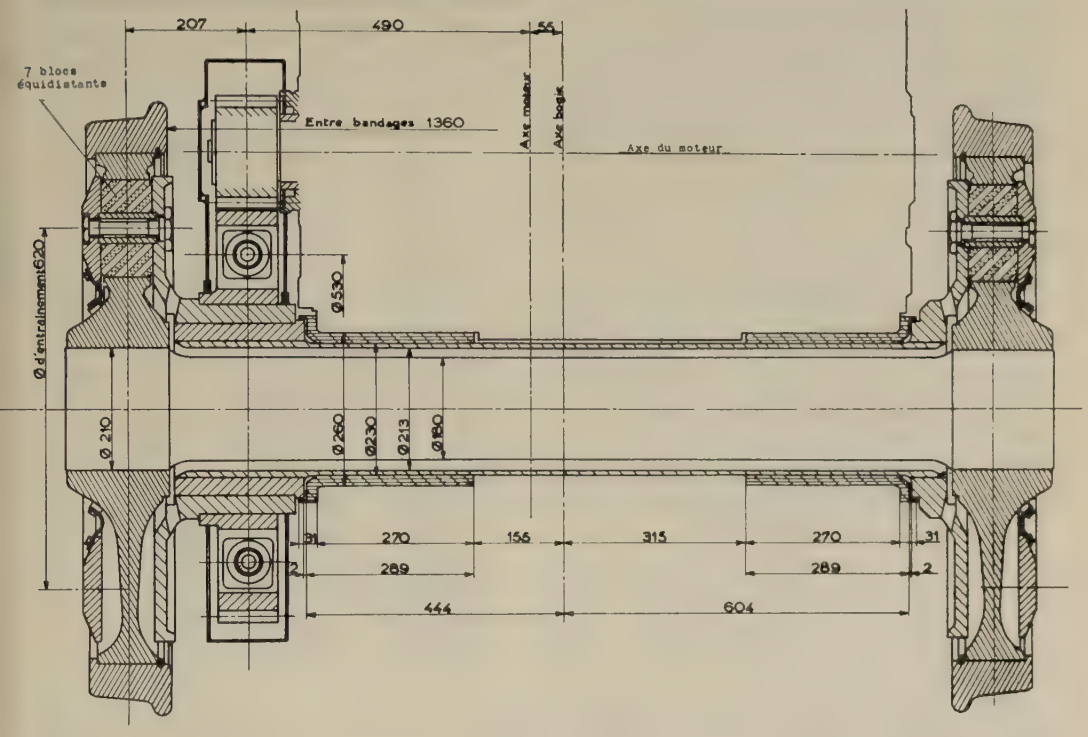
Figure 448 show the complete mechanism of one wheel (with the gears) of the STEFER motor coach No. 401, and figure 449 a complete bogie in elevation, plan and section. These two figures provide a very clear picture of the new Breda coupling and its arrangement.

Another Italian mechanism with rubber

([311]) Cf. figures 310-312, B_0B_0 locomotive, Gr. E. 424, Italian State Railways (FS).

units, manufactured by Breda, but developed by the Italian State Railways, FS, is that used on the new electric motor sets for high speed « elettrotreni », series ETR 301 of the FS. Contrary to the above mentioned sets, which have only three articulated vehicles, with the two end ones driving (312), the new set, which is the first of a series, has seven coaches with a total of six driving bogies, and is fitted as a de luxe train with a speed in service of 160 km (100 miles)/h as before the war.

We will return later to this mechanism



Plan SW LE. 18831 (450.618).

Fig. 450. — Horizontal section (i.e. from above) of driving axle of two motor coaches, series Z 5101-5154 (SNCF — S.E. Region) fitted with Alben-SW transmission.

Motor — SW.8304.B.
Gear ratio : 69/17 = 4.06.
Spur gear, modulus 10.3.
Flexible unilateral gear.
Bilateral transmission from hollow shaft to axle.

N. B. — The hatched portion (above the hollow shaft) of 260 mm diameter, along the hollow shaft is part of the traction motor housing.

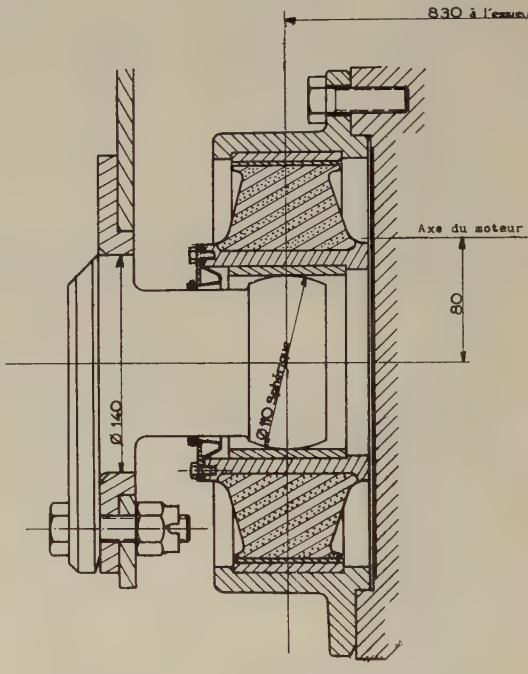
(312) See figures 205, 206 and 313 and relative description, p. 161 of *Vol. II* (*Congress Bulletin*, October 1948).

and this train, which was not yet in service at the beginning of 1953, and had then only carried out trial runs between Milan and Rome-Naples (« direttissime » lines, Bologna-Florence and Rome-Naples) at speeds up to 170/180 km (105-111 miles)/h. We will deal with the principles only, until further details are available from the Traction and Rolling Stock departments of the FS. The traction motor rests, flexibly, on a fixed nose from the bogie frame. The two arms of the motor, which in « tramway » suspension, encircle the axle, each rest by their bearing on a *hollow shaft* round the axle. This hollow shaft carries at the end a disc with driving pins (similar to those marked *f* in fig. 447), and these pins pass through holes in the large gear wheel which is fixed to the axle shaft. The driving wheels are consequently free from any drive mechanism.

Finally, another rubber mechanism has been developed by Breda, specially for tramway use. It is prematured to deal with this now.

We now pass to a fairly recent rubber mechanism of French/American origin. This is the Alben-SW type (313) used on some SNCF motor coaches. This transmission can be described as follows (fig. 450): the hollow shaft runs the full length of the axle; the arms of the traction motor rest through bearings on the hollow shaft (a frequent arrangement, as is the transmission, with which we shall deal) on which are fixed the large gear wheel and the gear case. At the two ends of the hollow shaft are plates on which are located 7 equidistant pins, which drive the wheels on the axles, by means of rubber pads.

These rubber pads are fixed on an armature sleeve and occupy holes in the wheels, provided for them. They are protected on the outside by metal cups



Plan SW. LE. 18209.

Fig. 451. — Flexible suspension of traction motor for transmission in fig. 450. The figure of 830 is from the nose suspension centre to the axle centre. The centre part (⌀ 110) is of A 33 case-hardened steel.

fixed by bolts which pass through the sleeve mounting of the pads thus forming the driving pins we have just mentioned.

The Alben SW transmission is at present fitted to two of the 54 motor units (electric motor coach sets) of the

(313) Patents 988179 and PV. 579161.

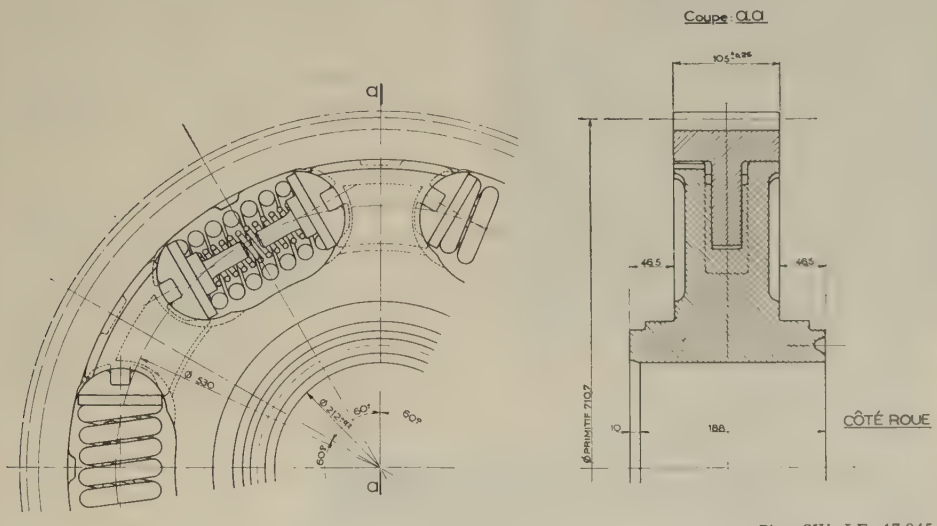
series Z 5101-5104 of the SNCF, South-East Region.

Figure 451 shows the flexible « nose » suspension of the traction motor, used only with the Alben-SW transmission.

The three figures 452, 453*a* and 453*b* show the resilient gears used for the two motor coaches fitted with this transmission. In figure 450, the circles in the body of the gear wheel represent the springs in figures 452-453*a*-453*b*, the Alben bilateral transmission being fitted, with a unilateral flexible gear wheel. Figure 453*b* shows the details of a group of two concentric helicoidal springs, mounted one within the other, with their precompression bearings; one of these spring assemblies is placed in each of the sockets in the gear wheel body.

In addition to its use on the two SNCF railcars mentioned above, the Alben-SW transmission is also to be used on the electric locomotive BBB 6002 (fig. 454) of the SNCF (314), supplied by the « Matériel Electrique SW » Company (Schneider/Westinghouse), which has nose suspended motors. The arrangement will, however, be different. We will deal with this further on in this Chapter.

The « Alben » transmission is of American origin (315) and has not so far been fitted to any railway vehicles; it



Plan SW. LE. 17.945.

Fig. 452. — Flexible gears of the two SNCF-S.E. motor coaches, series Z 5101-5154, fitted with Alben-SW transmission.
gear ratio : 17 : 69.
spur gear (modulus 10.3).

(314) See *RGCF*, July 1950, « Prototype electric locomotive BBB 6002, SNCF », 17 pages, 23 figures, plans and diagrams, THOMACHOT and ROSSIGNOL. Cf. figures 13 and 14 respectively with 451 and 452.
See also *ETT*, Nos. 82-84 of 1948 and 1-2 of 1949.
(315) Designed in its original form by ALBEN, engineer of the Westinghouse Electric Corporation, Pittsburgh (Pa. U.S.A.).

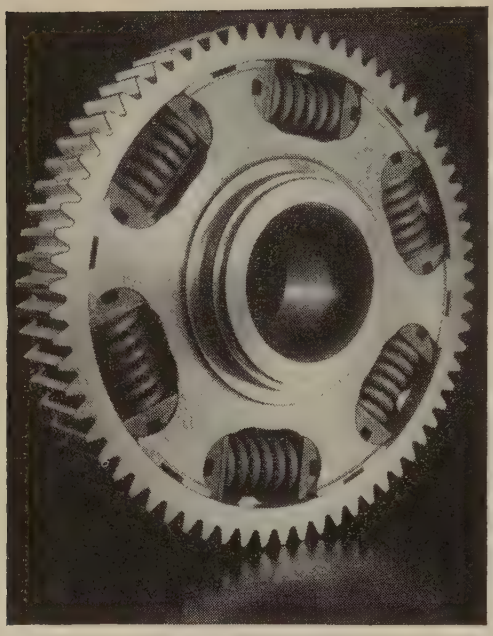


Photo SW.

Fig. 453*a*. — Photograph of gear in fig. 452.

has however been subjected to long stationary tests, both for durability and quality of the rubber blocks used. The present application by the SNCF has certain modifications by comparison with the early American type (315).

A definite opinion on its behaviour can be made only when the stock fitted with it has been in service several years. We can, in any case, see the close similarity with various other transmissions used during recent years, particularly the Breda types described above (cf. figs. 334-336 and 340 of *Vol. II* and 447 and 448).

Another rubber mechanism, which we shall mention here only *pro memoria* is that built by the « Siemens-Schuckert-Werke » (SSW) in Germany, which is fitted to the $B'_0B'_0$ electric locomotive, prototype No. E 10.003 of the Federal (West) German Railways, « Deutsche Bundesbahn » (DB) (316). One of the

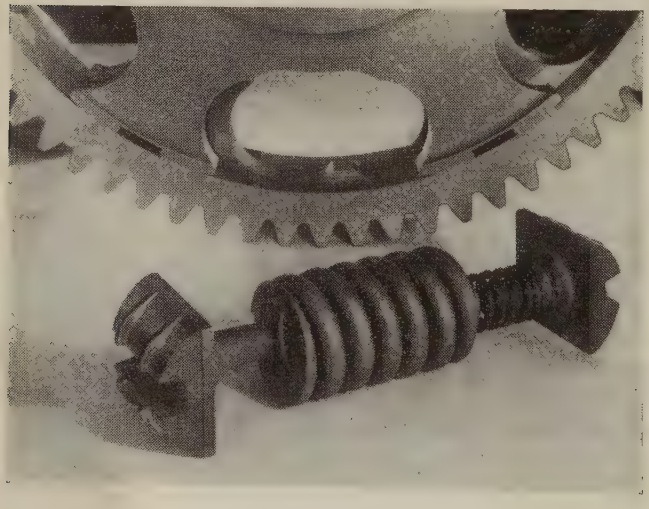


Fig. 453*b*. — Part of gear wheel of figs. 452 and 453a, dismantled, showing the detail.

Photo SW.

(316) See *EB*, January 1953, p. 7; cf. figure 19 in « Verzweigungsmechanismen als Antriebselemente elektrischer Triebfahrzeuge », KLOSS. — See also note (296).

prototype locomotives of the E 10 is mentioned in the two last columns of Chapter III.

Locomotive No. E 10.003 was still under construction at the beginning of 1953, and we shall therefore deal with the « Gummiringfederantrieb SSW » later.

We will now pass to recent applications (since about 1950) to locomotives or motor coaches of the following three helicoidal spring mechanisms:

A) « Brown Boveri » mechanism with springs and crossbar in an oil-bath (317);

B) « Sécheron I » mechanism with several pairs of twin springs (318);

C) « Quill cup drive » and « Federtopf-antrieb » with each spring held in a pair of cups (319).

In the latter category, we will also point out those which to our knowledge have been converted by substitution of rubber pads for the cupped springs.

A) *Brown Boveri mechanism with helicoidal springs and cross-bar, in oil bath* (320).

The most spectacular recent utilisation of this mechanism, currently known as the « Federantrieb BBC » is that on the two prototype locomotives Nos. 11401 and 11402, type $C'_0C'_0$, for the St. Gothard line of the Swiss Federal Railways (SBB — CFF — FFS); standard gauge of 1 435 mm; current system: single phase 16 2/3 cycles. These are the Ae 6/6, total adhesion, maximum speed: 125 km (77

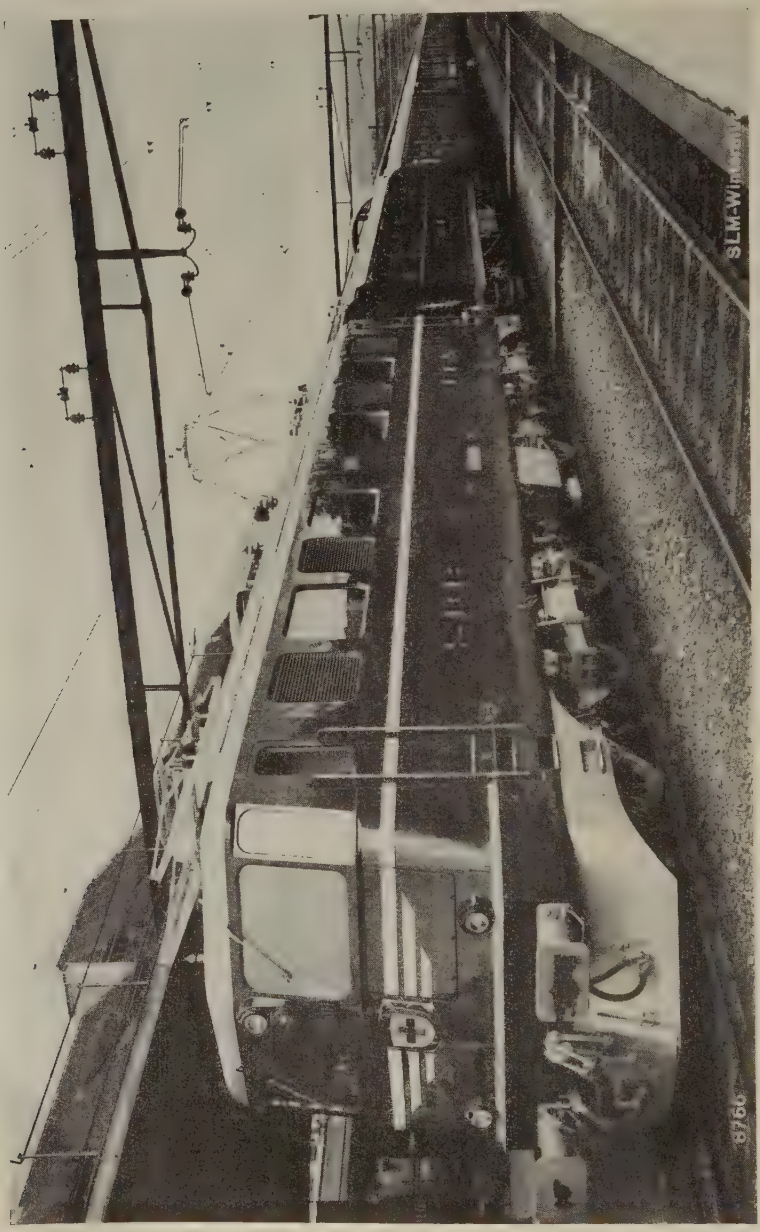
Cliché ETT.

Fig. 454. — Prototype electric locomotive BBB, No. 6002, 1948, of SNCF — 4 built by Schneider-Creusot and SW. The nose-suspension of the motors will be replaced by Alsen-SW transmission, different however from that in fig. 450.

(317) See *Vol. II*, pp. 118-150 (figs. 146-166, 170-190, 348-351, 355, 356 and 212*a*).

(318) See *Vol. I*, pp. 42-46 (figs. 73*a* and *b*, 87 to 101) and *Vol. II*, pp. 41-58 (figs. 37 to 66) and pp. 238-239 (figs. 296-297).

(319) See *Vol. I*, pp. 46-50 (figs. 102-109) and *Vol. II*, pp. 59-91 (figs. 67-107 and 108-112), and pp. 239-245 (figs. 298 to 304).



Cliché ETT.

Fig. 455. — Prototype locomotive class Ae 6/6, No. 11401, type C_0C_0, Swiss Federal Railways (St. Gothard line), on trial with train and dynamometer car at Thun station.

miles)/h. They are the first CC machines to be built in Switzerland, apart from some old (1921) rod-coupled, such as the 401 series of the RhB (Rhaetian Bahn) in the Engadine; the Seethal (SBB, Wildegg-Lucerne line), etc., locomotives.

The first of these machines was put into service at the end of September 1952 on the St. Gothard line (Lucerne-Chiasso and Zurich-Chiasso) after extensive trials. Figure 455 gives a view of this locomotive in Thun station during the trials and figure 456 is a dimensioned sketch with the principal characteristics ([320]), correcting the provisional sketch in figure 154*a*. The driving mechanism (with the gears) is mounted on one side only on a stub hollow shaft. Figure 457 shows the motor/gears assembly. We shall not describe this mechanism here; it has been clearly shown in figures 146-150 and 190 ([321]). In view of the hourly horsepower of 1 000 per axle, the number of radial arms (and spring) has been increased to 10, which has naturally increased the diameter of the gear wheel. Finally, figure 458 shows an axle completely assembled (without the motor) for one of these two locomotives, Nos. 11401 and 11402.

Up to the present this Brown Boveri spring coupling has not been used for powers in excess of 600 HP per axle. During the first four months of heavy service (autumn 1952) the mechanism for 1 000 HP per axle has not given rise to any difficulty.

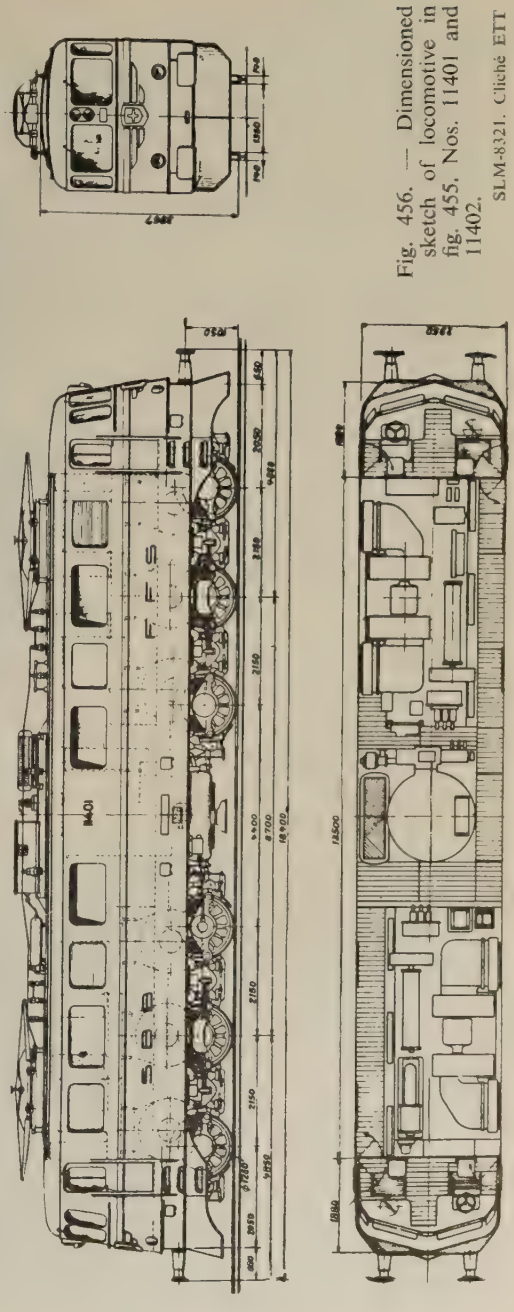


Fig. 456. — Dimensioned sketch of locomotive in fig. 455, Nos. 11401 and 11402.

SLM-8321. Cliché ETT

([320]) A preliminary dimensioned diagram of this prototype was given on p. 123 of *Vol. II* (fig. 154*a*). The dimensions remain the same, apart from the height of the body above rail, which is reduced from 4 000 to 3 967 mm.

([321]) *Congress Bulletin*, July and October 1948 (pp. 118-120 and 149, *Vol. II*).

The principal characteristics of these machines are as follows (322):

— hourly power; 6 000 HP at a speed of 74 km (46 miles)/h and a line tension of 15 000 V;
— hourly tractive effort at rail (under the same conditions) with part-worn wheels of 1 230 mm (4′ 0 7/16″): about 21 200 kg (46 737 lbs.);
— tractive effort in starting (at rail) about 32 000 kg (70 548 lbs);
— diameter of wheels — new — 1 260 mm (4′ 1 5/8″);
— maximum speed in service: 125 km (77 miles)/h;
— weight of mechanical part, including drive mechanism and compressor (without motor): about 66.1 t;
— weight of electrical equipment, about 55.9 t;
— auxiliary equipment (sand, oil) with crew; about 0.5 t;
— total (adhesive) weight in running order, about 122.5 t;
— load per axle, about 20.5 t;
— gear ratio: 37 : 82.

These two locomotives were built by the Swiss SLM (Société Suisse pour la Construction de Locomotives et de Machines) of Winterthur for the mechanical part, and by Brown Boveri & Co. of Baden for the electrical equipment.

Locomotive No. 11401 was put into service on the St. Gothard line at the end of September 1952; the second, No. 11402, at the end of January 1953. These locomotives cannot yet be fully used at their maximum speed, because speed in 1953 was still limited on the St. Gothard line, according to the section, to 70-100 km (43 to 62 miles)/h. These locomotives can haul, single headed on long gradients of 26 °/₀₀, a drawbar load of 600 tons. During the first months in service, drawbar loads of up to 640 tons have been worked.

It may be of interest in connection with these Ae $^{6}/_{6}$ locomotives and their drive and axle arrangement to say something about braking. They are fitted with Oerlikon automatic locomotive brake, with the settings, express passenger/freight. They are also equipped with anti-skid brakes designed by Oerlikon Machine Tools, *Buehrle & Co.*, Zurich-Oerlikon, Switzerland. The locomotives themselves, as well as a certain percentage of the train hauled can be braked electrically; on a falling gradient of 26 °/₀₀ (the maximum on the St. Gothard line) speed is limited to 70 km/h. Normal braking is by means of the Oerlikon valve mentioned above and the graduable brake.

With regard to other new applications of the same Brown Boveri mechanism, first used on the « Red Arrow » railcars of the CFF in 1933 (323), we may mention:

a) the Norwegian State Railways (NSB) locomotives and motor coaches,

(322) See *Bulletin des CFF*, No. 12, 1952, pp. 204-206, 5 figures, « New heavy locomotive for through trains on the St. Gothard line », E. MEYER.
Also *ETT*, Nos. 10-12, 1952, front pages and 121; *AFAC*, No, 172, 1952, pp. 21-24, « Electric Traction on the Gothard line — the new Ae $^{6}/_{6}$ of CFF », A. GACHE; *Gazette*, 28/11/52; *Neue Zürcher Zeitung* (Technik), Zurich, No. 7 of 26/11/52.
(323) See pp. 120/121 of *Vol. II* (*Congress Bulletin*, July 1948).

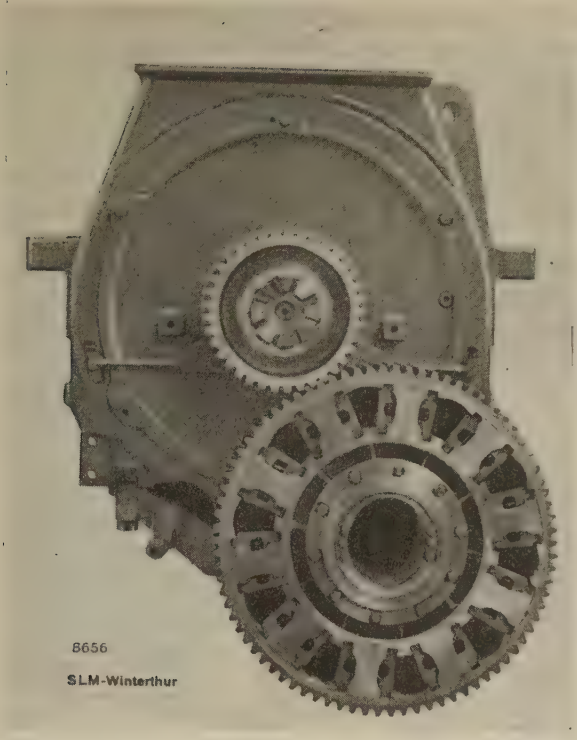


Fig. 457. — Motor group with hollow shaft and gears of locomotives in figs. 455 and 456; the springs of the Brown Boveri drive are mounted in the gear wheel. In the 10 circumferential holes engage the cross bar arms fixed on the axle (cf. figs. 146-150).

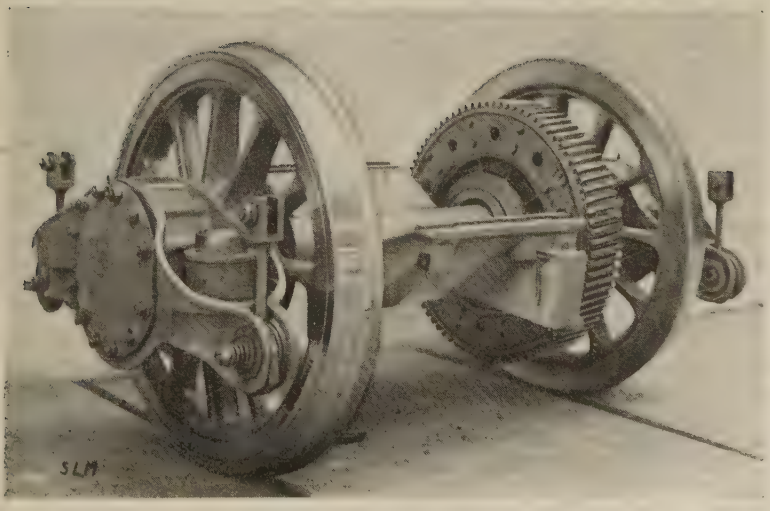
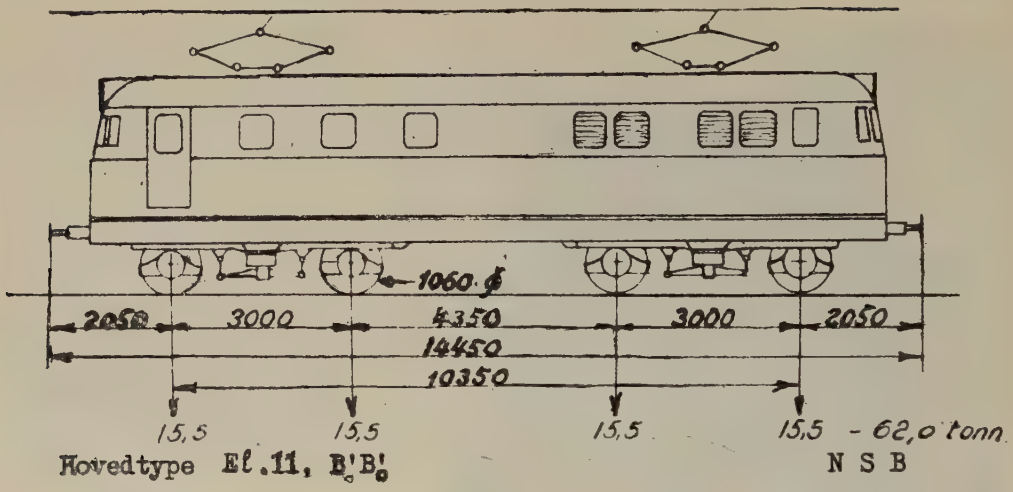
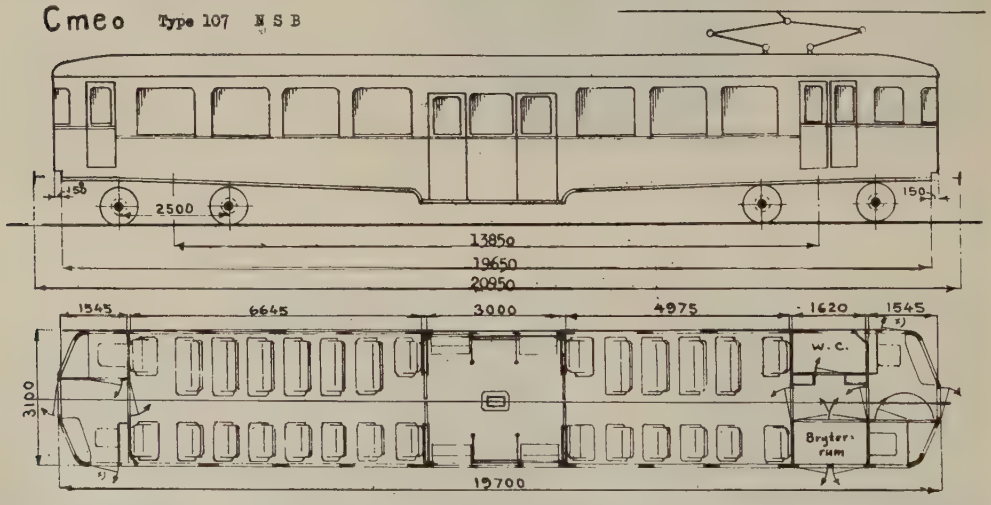


Fig. 458. — Complete driving axle (with boxes and suspension) showing the coupling (gear wheel mounted on stub hollow shaft) of locomotives figs. 455 to 457. The axle is shown here without motor or gearcase with a view of the gear wheel from inside (opposite to fig. 457) Unilateral drive and gear.



Plan NSB.

Fig. 459. — Diagram with dimensions and weights of 35 $B'_0B'_0$ locomotives, class El. 11, 1952, of the Norwegian State Railways, NSB. These locomotives have an arrangement similar to the Swiss CFF class Re 4/4, series 401. — Series Nos. 11.2078 to 11.2112 NSB.



Plan NSB.

Fig. 460. — Dimensioned sketch of Norwegian NSB motor coaches, class Cmeo, type 107, 1952/53. NSB, Series Nos. 18561 to 18578.

standard gauge, single phase, 15 kV, 16 2/3 cycles ([324]) as follows :

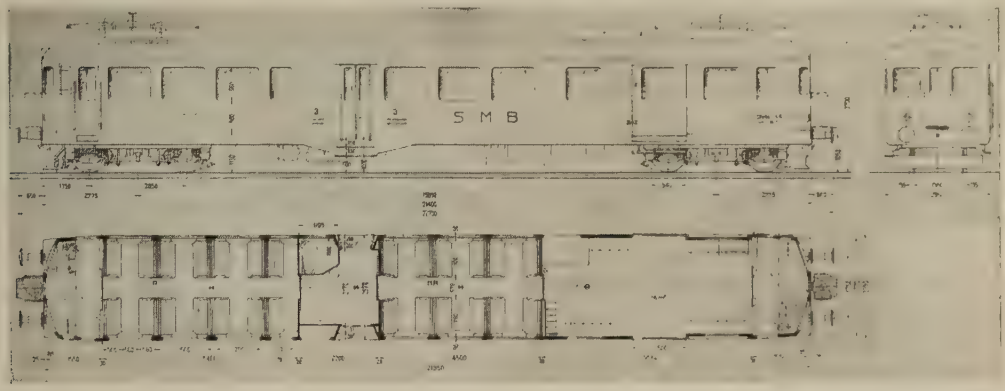
Thirty-five locomotives, class El. 11, type $B'_0B'_0$ (see fig. 459) very similar to the Re 4/4 machines of the Swiss CFF ([325]); hourly power : 2 120 HP at

([324]) See *Congress Bulletin ET*, February 1953, pp. 35-42, 7 figures, « Norwegian State Railways Electrification — Electric motive units ». E. SOLBERG. The large table p. 36 covers all categories of locomotives and motor coaches. Cf. figures 41, 42 and 44 of the article quoted, respectively with figures 173 and 348-354 of *Vol. II* and 460 and 300-345 of *Vol. II*.

([325]) See figures 184-186 of *Vol. II* (*Congress Bulletin*, October 1948).

a speed of 66 km (41 miles)/h; maximum speed in service: 100 km/h; gear ratio: 1 : 3.35. The weight of 62 tons is made up of 35 tons mechanical part and 27 tons electrical equipment. The first of these machines were put into service in the spring of 1952. At the beginning of 1953, there were already 10 in service, the remaining 25 being still under construction, at the « Thunes Mek. Verksted A/s », for the mechanical part, and the « Norsk Elektrish & Brown Boveri A/s » for the electrical equipment, both firms being located in Oslo.

Eighteen motor coaches with driving bogies, class Cmeo, type 107 (see fig. 460) of 636 HP, one hour rating at 39 km (24 miles)/h; maximum speed in service: 70 km (43 miles)/h. These vehicles were ordered in 1952 and are being built at « Skabo Jernbanevoghfabrik A/S », Oslo, for the mechanical part (coach work) and « Norsk Elektrisk & Brown Boveri A/S » for the electrical equipment. The coaches have 66 seats and a tare of 49 tons (326).



Plan SWS

Fig. 461. — Dimensioned sketch of motor coach No. 148, class CFe 4/4, Solothurn-Munster, SMB, Railway, Switzerland.

Weight of mechanical part : 36.1 t.
Weight of electrical equipment : 20.3 t.
Axle load (with pay load) : 15.5 t.
No. of passengers : 70 (52 seated).

b) The Rhaetian Railway (RhB), Switzerland (metre gauge, single phase: 11 kV, 16 2/3 cycles) six B_0B_0 locomotives, Nos. 605-610, type Ge 4/4. These machines are similar to those already described, and shown in figures 188 and 189 (327); they have a stub hollow shaft and mechanism at one side only. The manufacturers are as mentioned earlier (SLM, BBC, MFO & SAAS).

c) The Austrian Federal Railways

(326) Compare these details with those of *NSB*, Nos. 18535 to 18538, class Cmeo type 106 motor coach (p. 131, item 12, *Vol. II*) (*Congress Bulletin*, October 1948).

(327) See figures 188 and 189 of *Vol. II* (text, item 21, p. 149) (p. 616 of the *Congress Bulletin* for October 1948).

BBOe, normal gauge, locomotives as under:

Twenty-two Diesel-electric locomotives, one hour rating 730 HP, at 26 km (16 miles)/h; maximum speed: 95 km (59 miles)/h;

Eight locomotives, $C'_0C'_0$, one hour rating 5 400 HP, at 90 km (55 miles)/h; maximum speed: 120 km (74 miles)/h ([328]). Single phase 15 kV, 16 2/3 cycles.

These thirty machines also have stub hollow shaft and mechanism on one side only. They were ordered in 1952 and we shall return to them later.

d) The Solothurn-Münster Railway (SMB) [operated by the Emmental-Burgdorf-Thun, EBT ([329]), already mentioned previously], one motor coach, class Cfe $^4/_4$, No. 148, with two bogies (four motors); one hour rating of 1 120 HP, at 58 km (36 miles)/h; maximum speed: 90 km (55 miles)/h. This vehicle, also, was still under construction at the beginning of 1953; at the « Schlieren-Zürich SWD Works ». Since this is a fairly common type for secondary railways in Switzerland, and the EBT railway group is one of the large central Switzerland systems (standard gauge, single phase 15 kV, 16 2/3 cycles), we are including figure 461, a dimensioned sketch of the SMB motor coach No. 148. The exterior is similar to that shown in figure 187 (electric regenerative brake).

(To be continued.)

([328]) See *EB*, December 1952, under E., p. 303, figure 24.

([329]) See figures 41 and 187, *Vol. II.*

[621 .9 (485) & 625 .212 (485)]

Use of carbide tools for turning of wagon wheel sets,

by J. Olson,

Superintendent at the Gothenburg Workshop of the Swedish State Railways.

The wagon wheel sets of the Swedish State Railways are mainly built up according to figure 1.

The tyres of a wheel set are subject to remarkable strains both by running on the rail, over joints, tongues and crossings and by braking. The tyres are, therefore, produced of a proportionately very good material.

The specifications of manufacturing of tyres for the State Railways prescribe among other things that they are to be made of massive ingots of first-rate acid open hearth steel, free from defects, produced of Swedish pig iron and with the following chemical composition :

Carbon . . .	0.55 — 0.65 %.
Silicon . . .	0.25 — 0.45 %.
Manganese . .	0.60 — 0.80 %.
Phosphorus max.	0.040 %.
Sulphur max. .	0.035 %.

A test bar from the annealed tyre should give the following tensile figures :

Tensile strength . .	72 — 82 kg/mm² (45.71 to 52.06 t per sq. in.)
Elongation (1 = 5 d)	15 % min.

The weight of a usual wagon tyre, finish-rolled, is about 285 kg and the price about 260 Swedish crowns in February, 1953.

Earlier, the tyres were delivered with a thickness of about 80 mm in the tread, and the minimum tyre-thickness allowed after wear was 25 mm. Re-turning of worn tyres is usually not made, if the tyre-thickness at the repair is below 30 mm. According to calculations the wagon tyres are replaced after an average of 27 years. About 50 mm of the thickness of the tyre, or about 150 kg of its weight, will consequently disappear during that time. The material is consumed both through wear and through the re-turning necessary for the adjustment of diameters and contours of the tyres.

The wear of the tread during a running period or after 60 — 70 000 km is estimed to 1 — 2 mm.

The flanges are, however, also worn at the same time. If the underframe of a wagon is adjusted correctly, the wear of the flanges is generally not comprehensive. If, on the other hand, the underframe is askew, which is quite common on older, weaker wagons, the wheel flanges will often be very much worn, which will cause a considerable cutting depth by the re-turning of the tyres in order to obtain a quite satisfactory tyre contour.

It may, in this connection, be men-

tioned that the underframe is always subject to a careful inspection with adjusting, when wagons with flange-sharpened tyres are coming into the shops for repair.

The aforesaid wear of the tread and the flange is to be considered as a matter of common occurrence. However, about 10 % of the wheel sets, sent to the workshop for re-turning, are taken from wagons in traffic owing to slid flats in the treads.

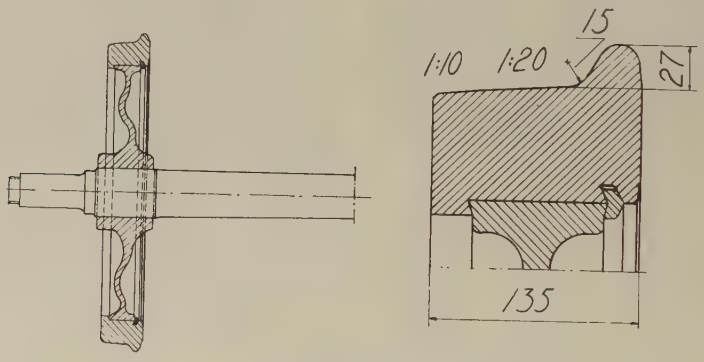


Fig. 1. — Swedish standard wagon wheel set.

There are slid flats of various types. The most common type is the flat which arises when the wheel set is stuck-braked and sliding on the rail so that a smaller part of the tread is worn off.

Another type of defects occurs, although more seldom, when material in form of extremely hard « scales » from the rail has been adhered to the tread by braking.

Such a tyre cannot be turned, before those « scales » are cut away with a chisel.

In addition to the aforesaid defects in the treads, which require re-turning, there are also in certain cases « cavities », which now and then are noticed in tyres during the turning. It is very time-consuming to re-turn tyres with such defects, while usually many cuts must be taken at a low feed and a low cutting speed.

Defects in the tread have a great influence on the running of the vehicles. The running will easily be disturbed and jerked, if the tread is much worn. Sharp worn flanges and slid flats or irregularities in the tread are perilous for the safety of traffic. On this account, it has been decided that the tyres should be re-turned at the repair, if they are worn more than 1,5 mm in the tread or the flange, or when a slid flat with a depth greater than 0,5 mm is found. As seen in the foregoing, there is only a diminutive part of the material that is worn off. The greater part of the material has to be cut off at the adjusting of the contour of the tyres. About 50 000 standard gauge wagon wheel sets are re-turned annually at the State Railways.

Most turnings are now made in heavy-

Fig. 2. — Two roughing tools in work; the left for the tread and the right for the flange.

duty wheel-set lathes of modern design. These lathes are double-slide lathes with four slides, placed two at each side of the lathe. The slides are at one side of the lathe arranged for rough-turning (fig. 2) and at the other side for finishing-turning with forming tools (fig. 3). Both the longitudinal movement of the head-stocks and the cross movement of the slides are direct-driven with one motor each. A special auxiliary motor admits a quick speed alteration of the driving device. All the operations are made by means of push buttons. A specially important part of the equipment of the working place is the semi-automatic charging and discharging device of the wheel sets, which device is served from the turner's working place (fig. 4).

The turning is usually made in the following way :— When the wheel set has been secured between the centres of the head-stocks and the drivers are locked,

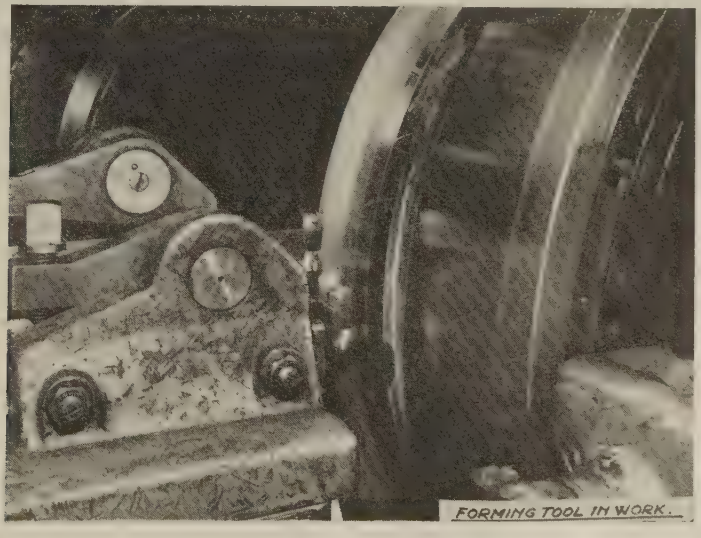


Fig. 3. — Two forming tools in work; the lower for finish-turning of the tread and the upper for finish-turning of the flange.

the turner moulds the worn wheel contour to be able to determine the cutting depth that should be chosen in order to obtain the standard contour. Then the two slides for rough-turning are advanced, each with two roughing tools, one put into work, one following close to the roughing tool for the tread outwards, and the other turning the flange. Guiding devices, which are incorporated in the slides, for the finish-turning, permit automatically the forming tools to give the

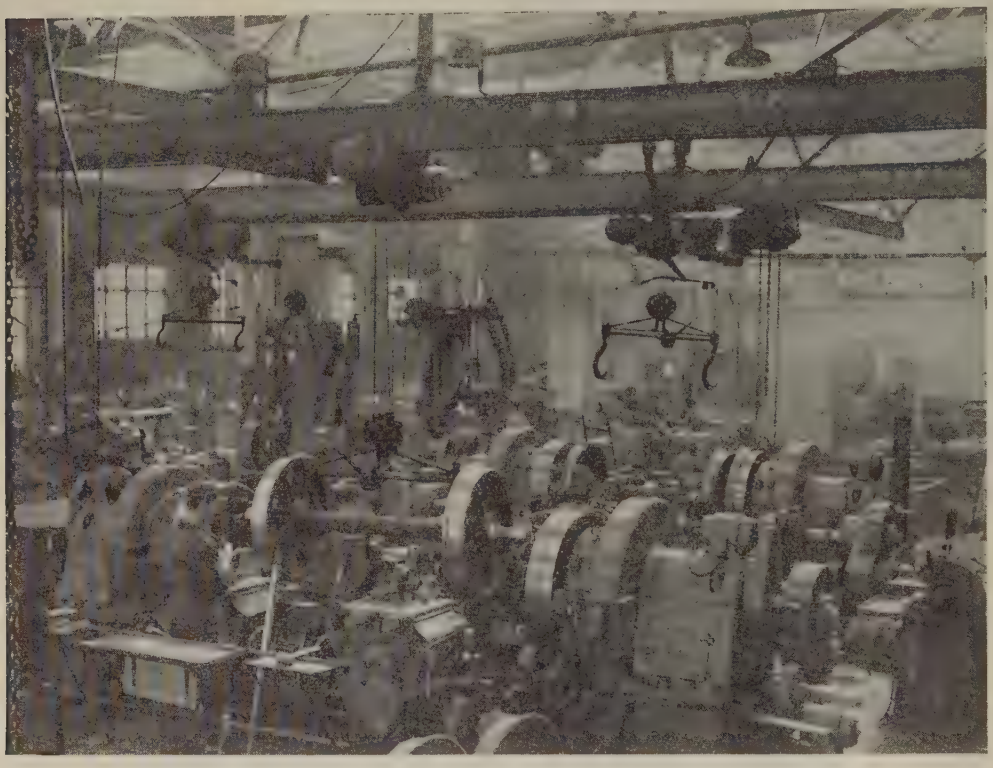


Fig. 4. — Two heavy wheel-set lathes with semi-automatic charging and discharging devices of the wheel sets. Each device is served from the turner's working place.

for the tread and one for the flange. The adjustment of the tools is made, so that the diameter of the wheels will be the same. The rough-turning of the tread is started in the throat of the flange. When in this manner the tread has been rough-turned in the throat, the two forming tools for the finish-turning are correct contour of the tread and the flange of the tyre.

These wheel-set lathes are, however, built for cutting with high speed steel tools. The very best qualities of the high speed steel managed quite well up to a cutting speed of 8 — 12 meters per minute in treads with normal hardness.

Most tyres that have been running under wagons fitted with compressed air brake are termed « hard-braked » tyres, i.e. the tread along the whole circumference of the tyres has a large number of small hard spots. In order to turn tyres with such hard spots without wasting too much high speed steel, the cutting speed must be reduced considerably at the same time as the cutting depth has to be increased so that the spots are « broken » up. The cutting depth must then be about 4 mm and the cutting speed be reduced to 3 — 4 meters per minute.

These circumstances caused that full use could not be made of the normal capacity of the lathe, and that considerable quantities of expensive tyre material, on an average of 25 kg per wheel set, must be cut off at every adjustment. Tyre material, removed in this way, came up to about 300 tons per year, merely in the workshop at Gothenburg. In consequence it was considered important to try new methods in order to improve the result, for instance through experiments with carbide tools and cutting off only a minimum of material by restoring the standard contour of the tyre.

For at least 20 years the carbide tools are known to be exceedingly effective for machining in hard materials. The first manufactured carbide tools of Swedish as well as foreign origin tested in Swedish wheel-set lathes failed, however, due to the fact that the tools were very brittle and splintered when the hard parts of the tread struck the cutting edge.

The Swedish manufacturers of carbide tools were quite acquainted with this weakness and worked untiringly in producing a carbide tool having sufficient toughness.

In the autumn 1947, the « Carbide Tool Department of the Söderfors Works » took a special interest in these problems. A quite new carbide tool quality, « Record U », was sent to the Swedish State Railways for testing, in order to establish the correct shape and tool angles, and to solve the question concerning the soldering method, and also whether carbide disk tools could be used for finish-turning of tyres.

After various experiments, which would be too extensive to describe in detail, the following data were established for carbide tools for turning of tyres.

1) The carbide tool shall be of a tenacious quality.

2) The tool holder shall be made of a very hard material and so heavy that there will be very few vibrations. (Cross section : 50 × 50 mm).

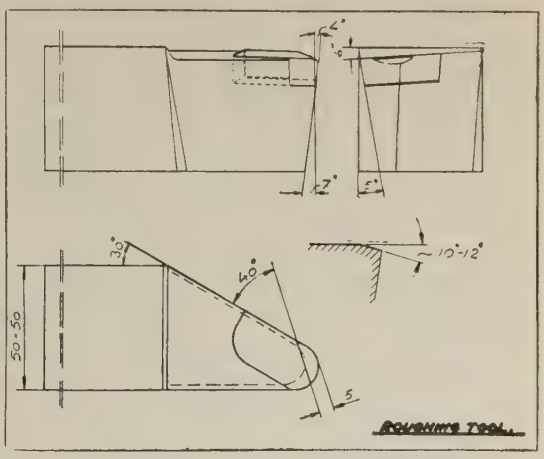


Fig. 5.— Roughing tool with tool angles indicated. The negative chipping angle also actions as chip breaker.

3) The soldering of the carbide tool bits must be made very carefully. Laminated shims of very close meshed steel gauze must be used.

chine. The tapered holder of the pin hitherto used is altered to a cylindrical holder with a nut. At present experiments are going on to good effects with

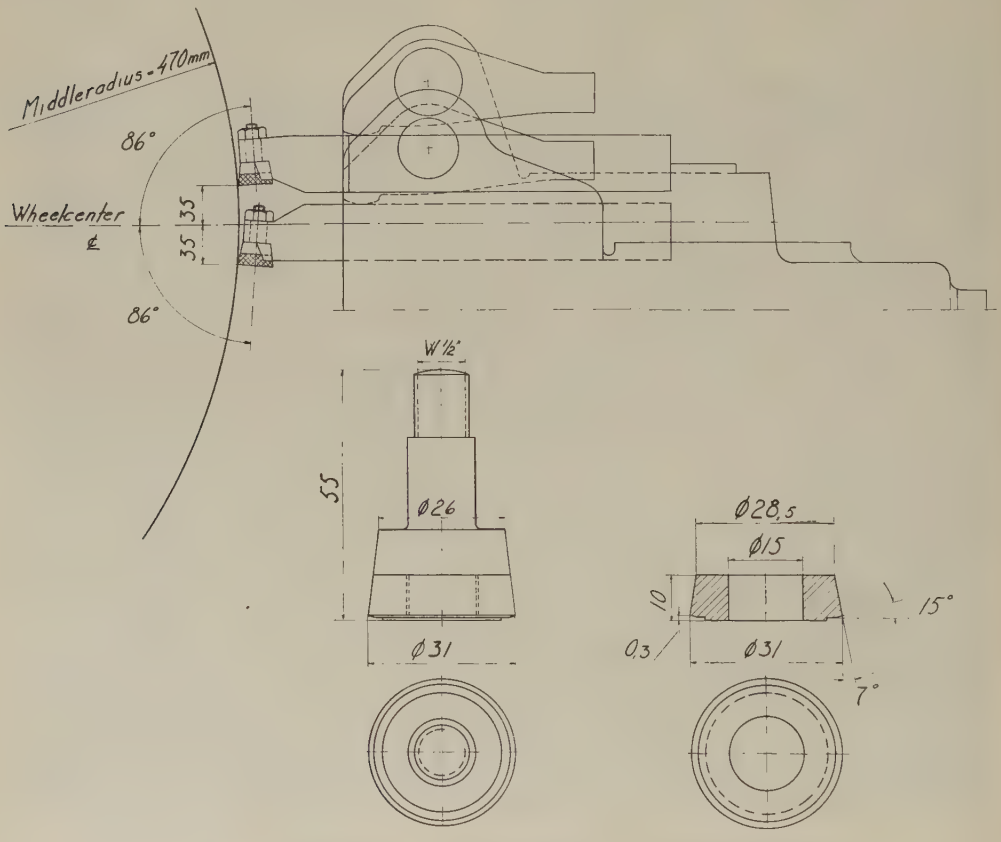


Fig. 6. — Finishing tools (disk-tools) with data and arrangement.

4) The tool angles of the roughing tool are to be made accordingly to figure 5. The negative chipping angle also actions as chip breaker.

5) The disk-tool (fig. 6) must have the shape of a ring and be soldered to a work-piece equipped with a pin and afterwards machined in grinding ma-

not soldered rings, clamped on to the pin.

6) With an angle of clearance of 7° and a negative chipping angle of 15° the best results have been obtained hitherto.

7) The chip breaking steps are absolutely necessary. They are to be made very small, 0.3 — 0.5 mm high. Other-

wise the friction will cause such a great heat on the cutting edge that the soldering will loosen.

8) Re-grinding and lapping must be made as soon as fractures occur on the cutting edge. This is to be made with a diamond grinding wheel, of grain 120 and 400 respectively with water cooling. The edge is sharpened after the grinding with silicon carbide hone, grain 400.

3 1/2 years' experiences have proved that the above mentioned views are correct. Even small divergences from mentioned grinding rules have caused considerable deteriorating of the result.

The turning of wagon tyres is made in the workshop at Gothenburg with carbide tools in two wheel-set lathes, type Lidköping Hj Sv 11. Tests in older lathes of a weaker design failed mainly owing to vibrations and low cutting speed. The cutting speed in one of the lathes has been 20 m/min. and in the other one 25 m/min. The feed of the roughing slides has been 1.35 — 2.84 mm per spindle-revolution and of the forming slides 3.25 mm per spindle-revolution. This feed has, however, recently been reduced to 3 mm in order to obtain a more even surface. The re-turning is as a rule made with two cuts, one rough cut with the roughing tools and one finishing cut with the forming tools.

Finding that some symmetrically worn tyres can be re-turned without roughing, tests have been made to re-turn with one cut using only the forming tools. Having checked, by advancing of the roughing tools, that the wheels are round, that they have the same diameter, and that the wear of the flange is quite normal, the forming slides are advanced and the tyres can be finish-turned without the loss of material caused of the rough cut. The turning of a wheel set can in this way be made within 7 — 8 minutes. Owing to the present design of the finishing slides this method can only be used in exceptional cases.

The result of the turning depends to a greater extent than otherwise on the attendance of the lathe. At the start of the turning, the turner has to survey carefully the appearance of the tyre, thus estimating the hardness of the tyre in order to be able to choose the correct feed. By the appearance of the chip and the surface of the tyre he has to estimate the state of the cutting edge and make tool-shifts if necessary. The turner has to have spare tools in sufficient number so that exchanging of tools can be made without loss of time.

As earlier mentioned, one of the advantages of turning of the tyres by carbide tools is that the hard parts of the surface and the rests of the slid flats, can be cut through. By doing so, it may, however, be feared that hard parts of material would be left in the surface, which could cause new flats. In some cases tyres with very hard slid flats have been turned in this way and put under wagons for testing in traffic. Very dull sounds were heard during the first kilometers. After the test run no marks could be seen on the ring. The tests are, however, still going on.

In order to obtain the economic purport of a change to the use of carbide tools, certain investigations were performed.

Tests were made in order to obtain information regarding the chipping quantity that was cut off both at the use of carbide tools according to the new method and at the use of high speed steel tools according to the old method. The tests were performed in lathes of the same type and by workers familiar to the respective working methods. The wheel sets were taken from the working procedure successively and, therefore, it can be estimated that the difficulty of operation was the same in both the lathes. After re-turning of 50 wheel sets in each one of the lathes a quantity of chips of 645.5 kg was weighed out at the lathe with carbide tools and a quantity of 1 312 kg at the lathe with high speed steel tools.

The quantity of chips will accordingly be 12.9 and 26.3 kg per turned wheel set, or in other words a re-turning can be made with carbide tools with less than half the loss of tyre material.

As aforesaid about 50 000 standard gauge wagon wheel sets are re-turned annually, thus giving a saving in tyre material of 50 000 (26.3 — 12.9) kg or 670 tons, equivalent to about 2 350 new tyres and a cost of round 610 000 Swedish crowns a year. Calculating with a reduced payment of interest, which is the result of the increased life of the tyres, there will be a profit being considerably greater.

An investigation concerning the choice of a favourable tyre-thickness at the procuring of new wagon tyres, taking into account the introduction of carbide tool turning, shows that the most economic tyre-thickness would be 55 mm instead of originally 75. A reduction in weight of 135 kg per wheel set and reduced hauling costs would accordingly be obtained. At present the tyres are delivered with a thickness of 70 mm in the tread.

Through this new procedure the time for the turning (machine time) has been reduced from 20.11 to 13.01 minutes. The labour cost has been reduced correspondingly. A study of the method showed that the total turning time from floor to floor at the turning of 50 wheel sets was on an average of 17.66 minutes per wheel set for the lathe with carbide tools and 24.76 minutes per wheel set for the other lathe with high speed steel tools.

Tool consumption.

Naturally hesitation occurs in the choice between two different turning tools when only the tool bit for the carbide tool is 12 times as expensive as the complete high speed steel tool. The question is especially how the values concerning cutting speed, feed and cutting depth should be chosen, so that they, at the most suitable tool shape, give the greatest possible output at the lowest costs. At first, the tests were made with the high cutting speeds common for carbide tools, but then the consumption of carbide tools were unreasonably high. This depended probably on certain deflections and vibrations in the tool holders of the lathe, which had a breaking-down influence on the cutting edges. Moreover, it was more difficult to guide the chips.

It seems as if the most economic result is obtained at the previously related cutting speeds, cutting depths and feeds.

It has further appeared from the tests that too large cutting depths should be avoided, for instance at wheels with the flange very much worn or at wheels with hard spots in the tread. In such instances the tread is turned with two roughing cuts.

Three types of carbide tool bits have been used :—

one larger, weight 94.6 g
(roughing tool for the tread);
one smaller, weight 53.4 g
(roughing tool for the flange);
one ring-shaped, weight 73.7 g
(disk tool for the form-turning).

One set of tools consists of :

2 roughing tools for the tread,
2 roughing tools for the flange,
4 disk tools for the form-turning.

The cost for a set of these tools amounts to 370 Swedish crowns.

The wear itself is very insignificant. The reason for the consumption of the carbide tools is in main the re-grindings, which have to be made when the edge has got defects or when the tool has burst. As a proof of the wear of the carbide tools can be informed that with one disk tool 1 953 tyres have been turned without any re-grinding of the cutting edge.

At above mentioned test-turning of 50 wheel sets the wear was so insignificant concerning as well carbide tools as high speed steel tools that the result of this turning is too uncertain to give any exact figures of the tool consumption.

The costs of procuring and all maintenance of turning tools with carbide tool bits have instead been investigated during the time from 1st July 1951 to 30th June 1952, when 15 364 wheel sets were turned. Material costs, wages and other expenses came up to a total of about 24 500 Swedish crowns or 1.60 crown per wheel set. The corresponding costs for turning of 19 957 wheel sets with high speed steel tools were about 36 000 Swedish crowns or 1.80 crown per wheel set at now ruling prices of high speed steel.

A comparison shows that the costs for the turning tools at the present level of prices are lower by turning with carbide tools than by turning with high speed steel tools.

Since the cutting edges of the carbide tools keep their sharpness better than those of the high speed steel tools and as the chip area is much smaller, the power necessary for the lathe will be reduced, which also means reduced wear on the lathe. A reduction in the cost of repairs has also plainly been observed.

The indirect profit, which has been specially appreciated in Gothenburg after the introduction of turning with carbide tools in two lathes, is that the increase of the capacity of the two lathes, in total about 12 turnings a day, has caused that the previously obligatory overtime has been withdrawn and that there is sufficient margin for an increase of the number of repaired wagons, without procuring another expensive lathe and accordingly an extension of the wheel shop. As before mentioned the tests are still going on, and special attention is made to receive an additional reduction of the cut off material without

deterioration of the quality of work. Provided that stronger slides for the forming tools are constructed, it seems to be possible to get the majority of the tyres turned with only one finishing cut by forming tools and simultaneously obtain an evener surface of the tyres.

The method has to great advantage been taken into use in all the workshops of the Swedish State Railways that have got modern wheel-set lathes.

Finally, it is to emphasize that the working method now related cannot claim to be considered as in any way original; it only shows that apparently insignificant details within the railway practice can give savings of great value for the country in the present situation.

[625 .212 (485)]

Flaw-detection methods for railway axles,

by N. Nyström,

(Superintendent, at the Tomteboda Workshop of the Swedish State Railways.)

(Excerpt from a Report to the « Nordiska Järnvägsmannasällskapet » *(Northern Railway officers' Association.)*

During the last decades, the danger of formation of fatigue cracks in railway axles has increased considerably because of the higher haulage speeds and axle-loads used nowadays. For reasons of traffic safety, it is essential that axles having such defects are detected and rejected for further use, and it is, therefore, of the utmost importance that infallible methods are devised for their detection. Thus, in August 1950, the « Northern Railway officers' Association » appointed a Special Committee to inquire into methods for the testing of railway axles.

This Committee included representatives of the railway authorities of the various countries belonging to the Association, i.e. Denmark, Finland, Norway, Sweden, and the Chief Research Engineer of a Swedish manufacturing firm of railway axles, the Surahammars Bruks AB, in the laboratories of which the necessary metallographic investigations, photography of cracks and ruptures, etc., were undertaken.

On the completion of their inquiry, in March 1952, the Committee submitted a report on their findings, a resumé of which is given below.

Fatigue cracks in railway axles are usually found :

1) In the *wheel seats,* immediately inside the inner end plane of the wheel hub, where corrosion of the axle may advance considerably the formation of cracks.

2) In *journals of plain-bearing axles,* if traces of so-called overheating cracks remain after an insufficient turning or grinding of the axle.

3) In *journals of roller-bearing axles,* at the inner end of shrunk-on bearings or of the inside tapered sleeve. In these cases, the formation of cracks is encouraged by corrosion.

Some instances of fatigue cracks at the inner radius of the axle-journal, under the end collar, have been observed, in cases where the radius has been heavily corroded — water will condense in this space which is cut off from lubrication and consequently, unprotected against corrosion.

4) With present-day dimensions of axles, cracks are very seldom found in the axle-shaft, i.e. the part of the axle between the wheel seats. Such cracks may occur as a result of very sharply stamped markings, or because of other defects in the surface of the axle.

The most common appearance of a fatigue crack is shown in the figures Nos. 1 and 2. A lot of cracks extends round the entire circumference of one

wheel seat, approx. 6 mm from its inner end. Figure No. 1 is a view, magnified 5 times, of a part of the corroded band, the width of which varies between 3 and 6 mm. At « S » on the inner edge of the corroded section some small fissures are visible. The axle was test drilled in order to find the deepest of these fissures — 44 mm — before breaking it in the laboratory to study the nature of the fracture. The rest of the cracks were found to be rather shallow.

Figure No. 2 shows the fracture through the deepest of the cracks. « A » denotes the fatigue crack, « B » the fracture of the same part of the axle, and « C » is a machined part of the section.

A fatigue crack caused by defects in the steel used is next described. A network of fissures was observed, forming a belt around the shaft of an axle, as shown by figure No. 3. One of the cracks was test drilled and found to be 14 mm deep.

Fig. 1. — Normal appearance of fatigue cracks in a wheel seat. The cracks are generally situated at the inner edge of the corrosion zone.

After removing a surface layer, 1.5 mm thick and 15 mm wide, only the transverse test-drilled crack remained, as illustrated by figure No. 4. A sample containing this crack was taken from the axle, and broken off. The rupture of figure No. 5 was obtained, showing a typical fatigue crack at the left of the drilled hole. When striking the sample a second blow, another break was obtained revealing still another

fatigue crack according to figure No. 6, having a depth of 4 mm below the surface.

Microscopic examination, showed that the material was heavily decarburised near the surface in the vicinity of the cracks, and that corrosion had penetrated from the surface into the interior, as illustrated by figure No. 7. The material in these parts must be considered burnt. The origin of the fatigue cracks was, apparently, the observed cluster of fissures in the decarburised surface layer, which had, in all probability, been occasioned by a too high temperature during the forging process.

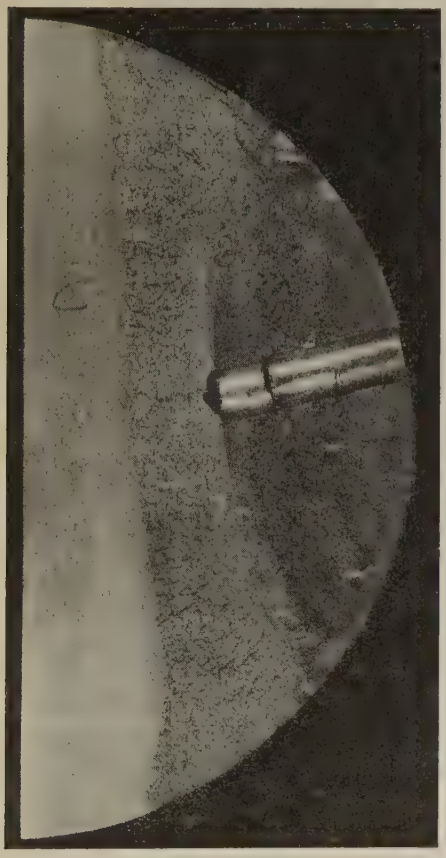


Fig. 2. — View of the rupture through the deepest crack of figure No. 1. « A » is the fatigue crack, « B » the break, and « C » a machined section of the ruptured surface. The photo also shows a hole, drilled to measure the depth of the crack.

As far as is known, no recorded axle ruptures have been due to *interior defects in the axle material,* although it is established that such defects do occur in some axles, as witnessed by figure No. 8, which shows a deep-etched longitudinal section through a wheel seat. Scattered, mainly radially orientated porosities are clearly seen. The existence of these flaws is probably due to the axle being taken from the top end of an ingot. The segregations in the centre also indicate that the axle comes from the top end of an ingot.

Older testing regulations.

Stipulations regarding inspection of railway axles have hitherto varied considerably with the various authorities. In Sweden, inspection was to be performed when the axle had seen 15 years of service, and afterwards at specified intervals, for instance, 3 years. The wheels were then pressed approx. 40 mm outwards to expose the zone where cracks generally occur, this zone to be minutely scrutinized through a magnifying glass.

The other railway authorities stipulated the wheels to be removed completely for chalktesting of axles on reaching a specified age, generally 30 years or more, and thereafter at regular intervals, the axle to be discarded at a predetermined length of service.

Fig. 3. — This photo shows a network of cracks on the surface of the central part of the axle — the material has been overheated during the forging process.

Newer inspection methods.

The inspection methods mentioned above are time-consuming, and afford no absolute certainty that all cracks are detected. Thus, more rapid and accurate methods have been devised, among which the following two seem to be the most suitable for the problem at hand.

Magnetic flux testing.

The principle of this method is the fact that particles of a magnetic substance

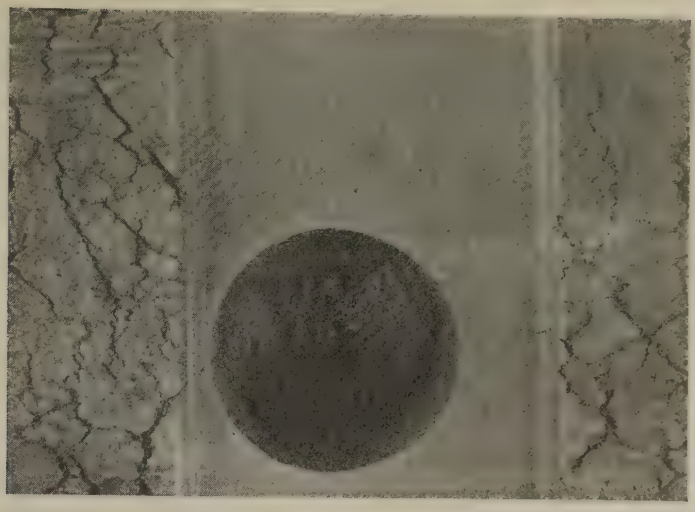


Fig. 4. — After turning away a surface layer of 1.5 mm thickness from the axle of figure No. 3, a fine crack remains, radiating from the drilled hole.

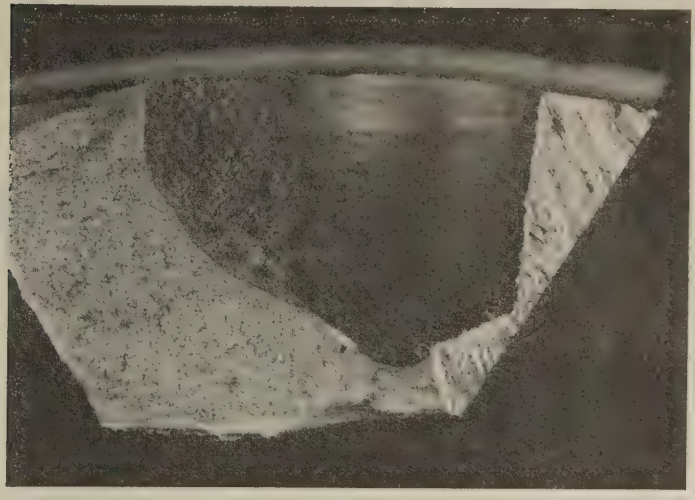


Fig. 5. — A test sample was mortized from the axle (figure No. 3), containing the crack. After breaking off, the above photo was taken, revealing a typical fatigue crack.

— such as black iron oxide and iron filings — will concentrate over a crack in the surface of a constructional element which is being magnetized, this attraction being due to the interruption of the magnetic flux athwart the edges of the crack. As, in axles, cracks are invariably transverse, the axle is magne-

Fig. 6. — On breaking the test sample a second time, another fatigue crack was revealed.

tized longitudinally by running low-voltage a.c. at high intensity — max. 1 000 amps. — through a solenoid surrounding the axle. A magnetic powder made up from chemically prepared, extremely finely divided particles, is blown on to the axle, or alternatively, the axle is wetted with a detecting fluid containing spongy iron particles in suspension. In the latter case, magnetic materials are often employed which will fluoresce in ultraviolet irradiation.

The method has proved very dependable, showing up even very minute transverse cracks. However, flaws in the interior of the material cannot be detected in this manner.

The method is rather expensive in use, as it calls for exposure of the parts of the axle to be inspected. Hence, the roller bearings must be removed to lay bare the journals, and the wheels pressed outwards approx. 40 mm to make possible the inspection of those parts of the wheel seats where cracks do generally occur.

Supersonic testing.

This method works on the same principle as echo-sounding, using oscillations of supersonic frequency, say 2.5 Mc/s. A sequence of pulses of very short duration are impressed on one end face of the axle, from where they travel along the axle, and are partially reflected by all obstacles in their line of propagation, for instance, the far end, shoulders on the axle, and other discontinuities, such as cracks, if any.

The equipment used for supersonic testing consists of a pulse-generator unit and a receiving-indicating unit, both equipped with piezo-electric quartz crystals mounted in probes of approx. 20 mm diameter, and connected with the generator and receiver, respectively, by means of flexible cable.

During testing, the crystal probes are placed against one end face of the axle being checked. The transmitting crystal

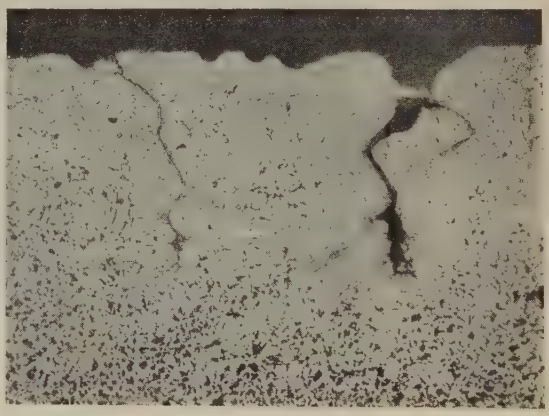


Fig. 7. — Microscopical examination of a section through the axle of figure No. 4 showed that the material was heavily decarburised near the surface, and that corrosion had penetrated from the surface inwards.

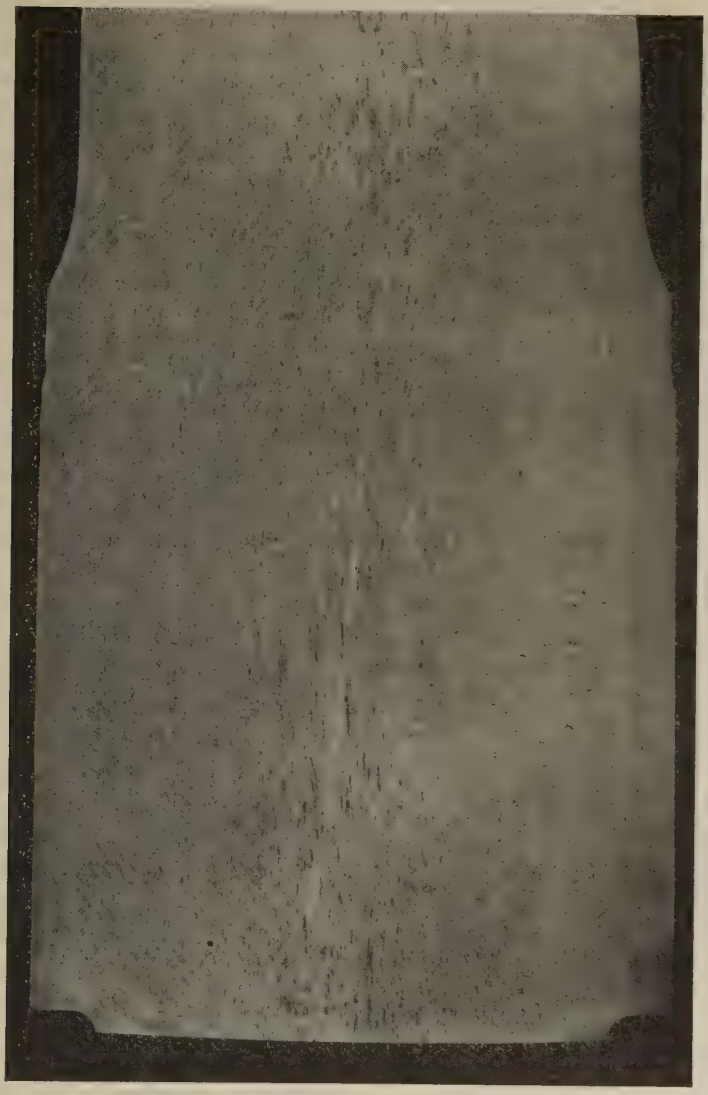


Fig. 8. — Certain axles show internal flaws. This photo displays part of a longitudinal section through an axle having scattered, mainly radially orientated porosities, to be seen to the right in the picture. The core of the axle abounds in segregations.

transforms the electrical pulses from the generator into supersonic waves which enter the axle. The echoes from the various parts of the axle are received by the second crystal, and are re-transformed into electrical pulses which are recorded by the indicator. This unit displays, on the fluorescent screen of a

cathode-ray tube, the echoes over a linear time-scale. The time elapsed between the emission of a pulse and the return of an echo is a measure of the distance between end face and flaw, and the positions of the flaws in the axle can, therefore, be read directly on the cathode-ray screen.

Supersonic flaw detectors have also been designed which use a single crystal both as transmitter and receiver. Special angle probes are used for the detection of cracks behind shoulders on axles.

The method generally does not disclose smaller cracks in the wheel seats and in the axle-shafts. Cracks in the axle-journals normally escape detection unless they are of considerable magnitude. Flaws in the interior of the axle — such as cavities, segregations and inclusions — are, however, detected without difficulty.

Unlike the magnetic flux method, wheels need not be tampered with, or roller bearings removed, when testing by this method.

Inspection is rendered considerably easier if the end faces are smooth — apart from punched markings — although there is no appreciable difficulty in obtaining good results also with roller-bearing axles having a wide key-way in the end face.

Conclusions.

From the above, it is evident that the magnetic flux method gives the most complete indication. As the operations accompanying this testing method require appreciable time, the method turns out rather cumbersome and expensive, and should be used only with old axles where fatigue cracks are more likely to occur.

Younger axles should be checked regularly for cracks by supersonic testing. Cracks will then be detected before reaching such depths that they cannot be removed by turning of the axle — the useful service life of axles can, therefore, be increased. Deeper cracks may be discovered at an early stage, so that such axles may be discarded, thereby avoiding rupture in service and the attendant traffic disturbances.

As cracks in the axleshafts and internal flaws are easily detected by supersonic testing, this method is recommended for routine testing of all railway axles — that is, also for old axles which are sent in to the workshops for overhaul, repair, or revision.

The crack-detection methods described above are recommended for use by the respective railways in Denmark, Norway, Finland and Sweden.

After studying these and other methods of crack detection in axles, such as inductive methods, and comparing various makes of supersonic testing equipment, the Committee have submitted the following draft of regulations regarding crack-detection methods and inspection procedure.

Draft of regulations regarding inspection of railway axles for cracks, turning of axles to remove shallow cracks, and marking of axles inspected.

Magnetic flux testing.

Axles above a certain age-limit shall be tested for cracks in axle-journals and wheel seats, with the wheels displaced outward by approx. 40 mm, by the magnetic flux method, this examination to be repeated at specified intervals.

Axles found with cracks in the wheel seats shall be discarded unless the cracks can be removed by turning the axle on a lathe — see below.

Axles found with cracks in the journals shall be discarded — regarding overheating cracks, see below.

The age-limit mentioned should, preferably, be specified only after comprehensive tests with the various types of axles. As axle dimensions, axle-loads and haulage speeds vary in the countries concerned, it is likely that different age-limits will be decided upon. Possibly, the age-limits will vary also within one country for different axle types.

Shallow cracks at the inner end of a wheel seat shall be removed by turning away a part of the width of the wheel seat. The diameter of the turned section of the wheel seat must not, however, be less than that of the adjoining section of the axleshaft, unless the railway authority concerned permitting. The length of the wheel seat must not be reduced by more than 15 mm, and the radius of the turned section shall be approx. 25 mm.

Such turning of wheel seats shall be effected at both wheel seats, even if cracks have been observed in only one seat. After turning and polishing, the axle shall be tested by the magnetic flux method as a supplementary check. If no crack is then detected, the axle may be re-entered in circulation, but shall be tested henceforth at 1-year intervals on being returned to main workshops. — The turned part of the axle shall be treated with « Dinitrol » or other anti-corrosive agent before reassembling.

Overheated axle-journals shall be tested by the magnetic flux method after trimming or turning, to ensure that no cracks remain in the journal surfaces.

After testing by the magnetic flux method, marking shall be made by punching the signature of the workshop, the ordinal number of the month, and the two last figures of the year on the inner end plane of the wheel hubs.

After removing a wheel-seat crack by turning, marking shall be made as above, followed by the letter S and a figure giving the thickness of the layer removed through the turning process, for instance, S1 or S2 for 1 and 2 mm, respectively. A 30 mm wide band shall be painted around the axle close by the wheel seat and on the wheel hub, using red oilpaint.

Supersonic testing

To maintain control of axles during the time before they are due for magnetic flux inspection and between such tests, all axles shall be regularly tested by supersonics. Supersonic inspection is to be made of every wheel pair arriving at a main depot for revision, and also of wheel pairs returned from the line for turning, etc. — in the case of roller-bearing axles, however, only if the axle-boxes have been removed. Axles in which the presence of cracks is suspected, shall be then tested by the magnetic flux method. Axles giving no clear bottom echo shall be rejected for further use; this does not apply, however, to axles made of puddled or other similar steels.

After a supersonic test revealing no defects, marking shall be made by painting on the shaft a circular spot of 75 mm diameter, using green paint, at a distance of 200 mm from either wheel seat. The two spots shall face in opposite directions to increase visibility.

Axles giving a clear bottom echo but indicating interior defects in the axle material, shall be marked in orange-yellow in the manner described above. In this case, the ordinal number of the month, and the two last figures of the year shall also be added beside the spots, using the same paint.

[621 .438 (73)]

What the Union Pacific gas turbines have been doing.

Railroad considers their performance so satisfactory as to warrant placing an order for fifteen more locomotives for 1954 delivery.

(*Railway Age*, December 29, 1952.)

One of the production locomotives in service on the Union Pacific.

Six gas-turbine-electric locomotives are now in regular service on the Union Pacific. They have been well received by the operating and maintenance personnel, according to A. H. Morey, project engineer, Locomotive and Car Equipment Department of General Electric Company, builders of the locomotives, and F. Fahland, general mechanical engineer of the UP. In a paper presented at the annual meeting of the American Society of Mechanical Engineers in New York, during the week of November 30, they outlined experience with this power on the road. The locomotives, they said, have been well received by operating and maintenance personnel,

though there has been the « usual amount of criticism » from both road and shop crews about details. Road foremen, dispatchers and superintendents, have « acquired a great deal of confidence in these locomotives », and there has been no hesitation in assigning them to the faster and more important trains. Their overall availability, operating costs and reliability, according to the report, have built up a general feeling of confidence and satisfaction on the part of all of the supervisory and management personnel.

Principal characteristics of the Union Pacific gas-turbine-electrics

Weight	550 000 lb.
Weight per axle	68 750 lb.
Rated HP (for traction)	4 500
Rated continuous tractive force	105 000 lb. at 12.9 m.p.h.
Maximum speed	65 m.p.h.
Balancing speed during hostling (Level-tangent track).	25 m.p.h.
Max. track curvature	21 deg.
Capacity (fuel oil)	7 200 gal.
Capacity (Diesel fuel)	1 000 gal.
Capacity (water)	845 gal.
Capacity (lube oil)	300 gal.
Capacity (sand)	37 cu. ft.
Rated full speed of gas-turbine	6 900 r.p.m.
Rated idling speed of gas-turbine	5 175 r.p.m.
Train air compressor displacement at full plant speed	246 cu. ft. per min.
Train air compressor displacement at idling	246 cu. ft. per min.
Auxiliary Diesel engine rating	220 HP
Auxiliary steam generator rating	1 500 lb. per hr.

There has been, naturally, a great deal of interest displayed by other railroads. Unfortunately, said the authors, a great many of the questions that have been asked have to do with values still unknown to them, and consequently they have not been able to give very satisfactory answers.

Further development of this type of motive power is one of the most interesting phases of the present operation, they explained, and one about which it is very unsafe to offer predictions. From a technical standpoint, there are many refinements which can be considered, such as waste heat boilers, recuperators, widening of fuel specifications and improvements in fuel rates. Many of these are interesting and, on paper at least, offer possibilities. Doing them, however, presents many problems. Undoubtedly, some of them will be done. In the meantime, the railroad and the builders are accumulating experience as to what the future locomotive will be like, and just what place these gas-turbine-electric locomotives will find for themselves on American railroads.

On the basis of its experience with the first General Electric gas-turbine-electric locomotive, built in 1948 and tested on several roads in 1949, the Union Pacific in 1951 ordered 10 units which essentially were duplicates of the pilot design, of which order the six now in service are a part. Without waiting for completion of this order, the Union Pacific this month further demonstrated its confidence in the performance of the gas-turbine-electric by ordering 15 additional units. The remaining four of the original order for 10 are scheduled for delivery in 1953 and the new order for 15 are for 1954 delivery.

The General Electric Company completed tests in Erie on its first gas-turbine-electric early in 1949. After short trials on the Nickel Plate and Pennsylvania it was consigned to the Union Pacific for extended hot weather and high altitude testing. This testing covered a fair percentage of the main line of the Union Pacific between Omaha and Los Angeles. Data were taken up to 120 deg. F. ambient temperature and 8 000-ft. elevation. A total of 105 732 miles were operated with 5 325 hours of fired time on the power plant.

Subsequently the locomotive was demonstrated on the Southern Pacific for a brief period, then returned to Erie. This first

locomotive had an eight-axle, B-B-B-B wheel arrangement with a fully loaded weight of 66 500 lb. per axle. It was rated 4 500 HP input to the generators for traction, but with low ambients and altitudes, the power plant would produce and the electric drive would accept 5 400 HP.

Locomotive performance.

As an experimental design, the performance on the Union Pacific was considered very promising. The A. S. M. E. paper points out that in 21 months operation on the UP the locomotive hauled a total of 348 608 000 gross ton-miles of freight, using 1 448 787 gal. of fuel. Train handling performance was very good and it was possible to utilize all the horsepower available under practically all conditions.

Performance on grades was pleasing with the locomotive handling 4 400 tons over 0.82 per cent grades at very satisfactory speeds. No trouble was experienced in tunnel operation. Riding qualities were especially good, the report states. The combination of 2-axle trucks coupled with a span bolster and the relatively long centerplate distance on the main cab minimized vibration and oscillation.

Crew acceptance was, in general, quite satisfactory. The characteristics of this locomotive were somewhat strange to the operating crews, although its manipulation followed Diesel practice very closely. It took a little time for the crews to get accustomed to the different characteristics and learn to use them advantageously, but this was quickly mastered. Very early in the test period there was considerable criticism from the crews about noise. After some changes were made in the deflection of the exhaust, this criticism rapidly disappeared.

Servicing of the locomotive was somewhat awkward because of the location of fuel filling openings and the excessive number of sand boxes.

The locomotive was shopped several times for design changes or repair of failed equipment. Its overall availability, discounting design changes, was approximately 70 per cent. Analysis of the availability data indicated that 90 per cent might be a reasonable goal.

Ten locomotives ordered.

In placing the order for 10 gas-turbine-electrics in 1951, the railroad requested a number of changes in addition to those proposed by the builder. The primary request was for an increase in capacity from 6 600 to 8 000 gal. of heavy fuel. The builder was able to provide 7 200 gal. and still meet the load limit of 71 800 lb. per axle set by the railroad. This capacity enables the locomotive to run 300 to 400 miles without intermediate refueling.

Other specifications by the railroad were 40-in. single-wear Class A wheels; improved equipment arrangement; improved piping; air brake modifications to meet Union Pacific practice; improved engine room drainage; and, in some cases, parts and materials better suited to railroad operation.

Although the 10 locomotives ordered were intended to be essentially duplicates of the first locomotive, they are actually different in many respects. For instance, it was decided that the production locomotive should have only one operating cab instead of two cabs as on the pilot locomotive. The cab is shortened from 80 to 78 ft. although the running gear remains essentially the same: — 83 ft. 6 1/2 in. between coupler pulling faces.

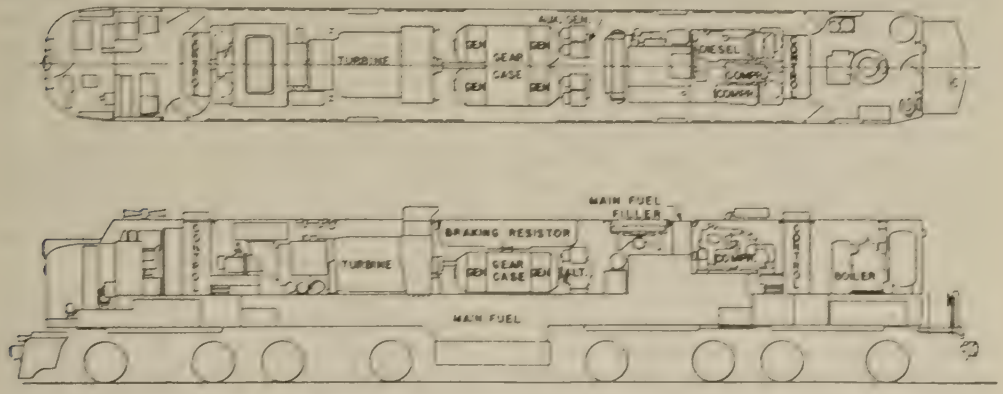
The new locomotive still has eight axles, all motored. The draft gear is located in the ends of the span bolsters, each of which rests on a pair of 2-axle trucks. The weight is increased to 275 tons. With 40-in. wheels instead of 42-in., the continuous tractive force is increased to 105 000 lb. at 12.9 m.p.h. Starting Diesel fuel capacity is increased from 600 to 1 000 gal. and boiler water storage for heating fuel is increased from 575 to 700 gal.

The closed system for return of heating condensate is retained. Maximum speed is 65 m.p.h. with 74/18 gear ratio.

The 7 200 gal. of heavy fuel are carried in the main frame, between the center-plate bolsters, with additional tanks above and below. Diesel fuel is carried in the main frame ahead of the number one bolster and water in a separate tank between the main sills, to the rear of the number two bolster, under the boiler room. The lubricating oil tank, batteries, main fuel and lubricant pumps are suspended below the main fuel tanks.

ment is the engine room with control cabinets at each end. This houses the main power plant and generating equipment, the Diesel engine and auxiliary generating equipment, dynamic brake equipment, air compressors and oil coolers.

The gas-turbine power plant is at the forward end of the engine room. It has a 15-stage, axial-flow compressor with inlet air silencer, discharging into six combustion chambers. The combustion gas passes



General layout of apparatus in the single-end production locomotive cab.

Equipment and arrangement.

The operating cab follows the conventional Diesel-electric locomotive pattern except for the power plant starting switch and notching guide on the engineer's instrument panel. Power plant warning signals are grouped ahead of the fireman. Another exception is the 20-notch throttle, which provides close control of power delivered to the traction motors.

The cab nose carries conventional air brake and other equipment, plus the starting Diesel fuel transfer pump.

The rear compartment — or boiler room — which replaces the second operating cab of the pilot design, houses the locomotive fuel heating boiler, emergency tool locker and miscellaneous equipment. Between the boiler room and the operating compart-

through a two-stage turbine and discharges from an opening in the roof. The power plant is started on Diesel fuel and runs on residual fuel oil.

Several changes were made to improve the servicing conditions in view of experience with the first locomotive. The main fuel filling opening was moved from ahead of the operating cab to the mid-part of the locomotive. A dog-leg fuel tank is used to provide better filling flow characteristics through the length of the long tank in the platform of the locomotive. As a result, fueling time, under the spouts, was reduced materially. The sanding requirements were reviewed, with the result that 8 of the 16 filling openings originally used were eliminated.

The traction control arrangement was left essentially unchanged. The power plant

starting was altered to the extent that as far as the operating crews are concerned, it is now concentrated in a single four-position switch on the dash in front of the engineman. After the initial starting of the Diesel engine in the terminal, the Diesel engine, the main power plant and the hostling control for the locomotive are all actuated by this one switch. This switch is mechanically interlocked, and provided with indicating lights, so that it is almost physically impossible for an engineman to mishandle the starting of the power plant, or control of the locomotive. The power plant regulator was simplified by the elimination of some of the speed steps, and a simpler two-position Diesel engine throttle operator is used. Series and parallel operation of the motors in hostling was also provided to allow a higher balancing speed with a light locomotive while hostling.

A great deal of attention was paid to the maintenance problems, particularly the removal and reinstallation of assemblies and subassemblies. The resulting locomotive, although not perfect in this respect, is a distinct improvement over the first model. There are one or two subassemblies which require series removal of other parts.

However, the main power plant, the main gear-generator assembly and the other major assemblies can be removed and replaced without removal of other equipment or units. The gas-turbine unit or gear-generator unit can be removed from a locomotive and replaced by another unit and the equipment run without realinement. The heating boiler and the train air compressors were relocated to provide better accessibility and easier removal.

Some of the more desirable characteristics of these locomotives are :

— Short length compared with other types makes them easy to handle in yards and shops;

— Excellent riding qualities and absence of irritating vibration make them attractive to operating crews;

— High horsepower permits high-speed train operation, except under very adverse temperature and altitude conditions;

— Elimination of reciprocating parts should provide dependable power at low maintenance.

Operation of new locomotives.

Six of these locomotives were delivered between February and August, 1952. Concerning their performance, the report states that, in general, train handling abilities have proved better than those of the pilot locomotive. There has been little difficulty in train starting. The first locomotive delivered was slippery on the front truck. This was overcome by ballasting and by the addition of a manually operated power reduction switch in the circuit supplying the front pair of traction motors. The locomotives are said to be still somewhat sensitive to poor rail conditions.

The centralized semi-automatic starting control on the main power plant and the Diesel engine has been well received by the engine crews. This feature has made it practical to shut down the main power plant under standby conditions, largely overcoming the handicap of high fuel consumption at idle speed. Hostling movements in the yard are practically all made with the auxiliary Diesel engine. Some long descending grades are often handled with the main plant shut down and with the auxiliary Diesel engine furnishing power for the air compressors. The net result has been a somewhat lower fuel consumption than that recorded on the pilot locomotive. The saving on long descending grades, however, is a dubious economy since the dynamic braking cannot function unless the main plant is running. So the fuel saving is somewhat offset by brake shoe wear. Consideration is being given to supplying motor field excitation for dynamic braking from the Diesel generator.

Practically all of the operation to date has been on a 175-mile mountain division between Green River, Wyo., and Ogden,

Utah. The elevation varies from approximately 4 300 to 7 200 ft. The first 65 miles eastbound from Ogden is a helper grade of approximately 1.14 per cent. Ruling grades over the balance of the run do not exceed 0.82 per cent. The locomotives handle trains weighing up to 5 000 tons. Rated tonnage over this run is 4 890 tons.

Total fuel consumption is currently averaging 4.28 gal. per 1 000 gross ton-miles.

The locomotives are averaging approximately 9 000 miles per month which is quite high for so short a run. This must be discounted to some extent because of the special attention and supervision they are receiving during their initial service.

Locomotive servicing.

Servicing, the report states, usually begins at the time the train arrives at the yard. A trained man, either a manufacturer's representative or railroad employee, boards the locomotive and makes a preliminary inspection while the train is moving through the yard. The locomotive is then cut off from the train and hostled to the servicing pit where it is given a rapid but thorough inspection and cleaning. At the same time that Diesel fuel is supplied, the steam generator is blown down and supplies are put on board. The locomotive then backs to the next station where it takes sand and heavy fuel. Then another move is made in the same direction for boiler water. After a move to the turntable, the locomotive is ready for the next trip. This servicing operation normally requires about 45 minutes from pit to ready track although it has been accomplished, under pressure, in 20 minutes.

The servicing operation just described occurs frequently enough to be considered normal, though additional work is often required. One or two of the joints in the fuel oil, lubricating oil, water or steam pipe system may be found to be leaking. These are tightened during the servicing operation. Occasionally, a failure requires one of the many pieces of small equipment to be replaced or repaired.

The difficulties encountered.

The locomotives have not been in service long enough to have needed heavy maintenance. The required monthly, quarterly and semi-annual inspections have so far been adequate to care for them. This, of course, excepts the troubles encountered in a new design of power plant and locomotive. These troubles have fallen into several general classifications :

First are the nuisance troubles inherent in any new design. While serious from the standpoint of designing motive power, these are usually small items, more or less readily fixed.

Then there are troubles resulting from manufacturing defects and inadequate parts or material. The report indicates that there have been relatively few road failures, only three of which can be considered serious. Two of these were caused by failed traction-motor pinions. The gears and pinions are a standard Diesel-electric type. While horsepower transmitted is somewhat in excess of general previous experience, these failures have been ascribed to défective material. The other serious failure occurred to the first turbine after approximately 1 100 hours and can be considered a design defect in the stationary parts. This has been corrected by progressive removal and modification of each turbine in service, using one spare turbine to keep the locomotives in operation. There has been somewhat excessive wheel tread and flange wear. This could be caused by excessive loading, unsuitable wheel material, or somewhat higher power delivery per axle than is customary on Diesel-electrics.

There are also problems of fuel system equipment such as metering pump, fuel nozzles and combustion changers which have had difficulty handling the low-cost residual fuel oil that must be used if the gas turbine is to be economically a serious competitor of the Diesel engine.

These problems are not considered insurmountable, and while the cost of scheduled heavy maintenance has yet to be deter-

mined and evaluated, the handling of the troubles encountered so far has indicated that the locomotive is well arranged to minimize expense of heavy maintenance.

Development work is constantly under way to correct faults and to improve the locomotives. Major improvements have been made in the gas turbine power plants themselves, especially in the combustion chambers and turbine first stage nozzle. Many small problems have been solved; and while each one seems small, the aggregate has resulted in much improvement to the locomotives.

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Bull. of the Int. Ry. Congress Ass., No. 6, June, p. 303.

MELDAHL (K.R.). — **Dynamic forces on railway wheel sets.** (7 800 words, tables & figs.)

1953 **656** .223.2

Bull. of the Int. Ry. Congress Ass., No. 6, June, p. 330.

ŽIVKOVIĆ (D.S.). — **Determination of the number of wagons and locomotives required for the goods traffic.** (7 000 words, tables & figs.)

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Bull. of the Int. Ry. Congress Ass., No. 6, June, p. 354.

WIENECKE (H.). — **The effects of soil movements due to the working of mines.** (8 000 words.)

1953 **385** (09.2

Bull. of the Int. Ry. Congress Ass., No. 6, June, p. 370.

OBITUARY : AUGUSTE MARGUERAT. (500 words & photographs.)

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